DEC 18 1939

SIGMA XI QUARTERLY

VOL. 27 WINTER, 1939 NO. 4

40TH ANNUAL CONVENTION COLUMBUS, OHIO, DECEMBER 28

IN THIS ISSUE

BASS ON HOUSING AND CONSTRUCTION INDUSTRY

McCUTCHEON ON LITERATURE AND SCIENCE

GRONDAHL ON IMAGINATION AND PROGRESS

CIRCULATION THIS ISSUE OVER 18,000

OFFICERS OF SIGMA XI

President.....GEORGE A. BAITSELL
Yale University, New Haven, Conn.

Secretary.....EDWARD ELLERY
Union College, Schenectady, N. Y.

Treasurer.....GEORGE B. PEGRAM
Columbia University, New York, N. Y.

EXECUTIVE COMMITTEE

DAYTON C. MILLER.....Case School of Applied Science, Cleveland, Ohio
Term expires January, 1940

ROSS AIKEN GORTNER.....University of Minnesota, Minneapolis, Minn.
Term expires January, 1941

E. J. LUND.....University of Texas, Austin, Tex.
Term expires January, 1942

HARLOW SHAPLEY.....Harvard University, Cambridge, Mass.
Term expires January, 1943

C. D. ANDERSON.....California Institute of Technology
Term expires January, 1944

W. F. DURAND.....Leland Stanford University, California
Term expires January, 1940

C. E. DAVIES.....New York, N. Y.
Term expires January, 1940

FINANCIAL ADVISORY COMMITTEE

ROGER B. WILLIAMS, JR., Cornell '01.....New York, N. Y.
H. DEWITT SMITH, Yale '08.....New York, N. Y.

ALUMNI COMMITTEE

C. E. DAVIES, Rensselaer '14.....New York, N. Y.
FREDERICK B. UTLEY, Yale '03.....Pittsburgh, Pa.
HENRY G. KNIGHT, University of Washington '08.....Washington, D. C.
DONALD H. SWEET, Case '13.....Chicago, Ill.
FLORENCE R. SABIN, Johns Hopkins '24.....Denver, Colo.

Assistant to the Secretary

MISS ELIZABETH C. WILKIE, Union College.....Schenectady, N. Y.

Published at Burlington, Vermont, by the Society of Sigma Xi

ANNUAL SUBSCRIPTION $1.00 **SINGLE COPIES 25 CENTS**

Change of address of chapter members and associates should be communicated to chapter secretaries and to the National Secretary.

Subscriptions should be sent to the National Secretary, Edward Ellery, 187 College St., Burlington, Vt., or Union College, Schenectady, N. Y.

Manuscripts should be sent to the National Secretary at Schenectady, N. Y.

Entered as second-class matter at the Burlington, Vermont, post office under the Act of March 3, 1879. The SIGMA XI QUARTERLY is published at 187 College St., Burlington, Vt., Spring, Summer, Autumn, and Winter.

SIGMA XI QUARTERLY

VOL. 27 WINTER, 1939 NO. 4

In Memoriam

DEAN FLOYD K. RICHTMYER

Sigma Xi Member, Alpha Chapter, 1904
Sigma Xi Executive Committee, 1917-1922
Sigma Xi National President, 1924 and 1925

In sincere sorrow and with profound appreciation of his splendid service to Cornell University, to the Society of the Sigma Xi, and to the cause of scientific research; and of his brilliant contributions to the advancement of knowledge in his chosen field of physics, the national officers of our Society announce to the membership at large the sudden death of Dean Floyd K. Richtmyer, November seventh at his home in Ithaca, N. Y. Investigator, author, university professor and dean of the graduate school, Dean Richtmyer was well known in academic and scientific circles in this country and abroad.

His research and study of x-ray phenomena gave him an international reputation. His "Introduction to Modern Physics" was widely used. He was identified with the National Research Council from its foundation and was chairman of its division of physical sciences. He served the United States Bureau of Standards as physicist, was an investigator in the research laboratory of the General Electric Company, and during the

World War was a radio engineer in the Signal Corps of the United States Army.

From the time of his election as a member of the Society of the Sigma Xi in his graduation years at Cornell in 1904, his interest in the purpose of the Society and his active participation in the great forward movements of the national organization were continuous. He served Sigma Xi as a member of the national executive committee, as the national president, as chairman of the committee on constitutional revision in 1922, and during the current year as chairman of the committee on the important work of perfecting the editorial management of the SIGMA XI QUARTERLY.

Dean Richtmyer will be profoundly missed in the councils of Sigma Xi and in educational and scientific circles everywhere, in this country and in a large area in Europe.

THE 40TH ANNUAL CONVENTION

The 40th annual Convention of the Society of the Sigma Xi is scheduled to be held in Columbus, Ohio, December 28 next. Among the important items of business which the Convention will be called upon to consider are the following:

a. Petitions for charters for chapters from the University of Southern California and the Virginia Polytechnic Institute.

These printed petitions were distributed to the chapters November 1.

b. Reports of Committees on the QUARTERLY and the Membership Structure.

c. Reports of the President, the Secretary and the Treasurer.

d. Election of a President, a Secretary and a Treasurer for the ensuing biennium, and of a member of the Executive Committee and of the Alumni Committee for a five year term.

The Nominating Committee is composed of President Karl Compton, Massachusetts Institute of Technology, Chairman, and Professor P. H. Mitchell, Brown University.

Chapters may make suggestions to the Committee direct, or through the National Secretary.

e. The 18th annual Sigma Xi lecture will be given by Professor Kirtley F. Mather on "The Future Man as an Inhabitant of the Earth."

HOUSING AND THE CONSTRUCTION INDUSTRY

FREDERIC BASS
University of Minnesota

The word "housing" gives rise to differing pictures depending upon one's avenue of approach. It represents a many-sided subject and several series of lectures presenting views of other than those of architects and engineers would be necessary to view all sides of it. The engineer is constantly measuring and measuring with such varying degrees of precision as may be desirable or possible within the time and means available. The estimate of housing now presented does not attempt a high degree of precision. Rather, it is intended to roughly approximate the magnitude of housing and the construction industry to which the technical activities of the civil engineer are directed. In viewing his problems, the engineer seeks to see them in correct relation to their origins and surroundings, both of which may influence his technical work. A brief reference to some of the origins of housing provides our introduction.

In the age-long struggle for existence, man and the other creatures of the earth have waged ceaseless warfare against their enemies and survival has depended upon their ability to adapt themselves to their environment or to modify it.

About 700 years ago, man began to change his way of thinking; he commenced to apply his innate power of observation and reason to his experiences with his environment. He discovered that most of the laws of nature were independent of and greater than human hope. His new philosophy required quantitative measurements of space, time and energy and he invented the instruments and tools which enormously extended his range of knowledge, which under rational analysis in the last century has modified his physical environment more than in all previous recorded history. One of the results is the modern house.

Our four great industries of manufacture and construction, of transportation, of communication and of power production have in recent years depended more and more upon scientific research which in the last two decades has increased a hundred-fold. Effort has been principally devoted to control of physical, chemical and biological forces and materials, and directed toward applications to human use. Enormous new wealth has been produced. The total effect of the application of science upon human society has not been foreseen; new problems of friction, waste and lost motion have been created in the *mechanism of society* which must be solved in order that the full benefit of physical sciences may be realized. The construction industry, for example, found to be in command of a multitude of materials, physical forces and processes, because of its unorganized *human* forces, is powerless to operate effectively and economically. Housing, which is a part of that industry, for the same reason, is not available to the extent warranted by potential national resources.

CHARACTER OF THE HOUSING PROBLEM

To the architect or the engineer it may seem natural to view the housing problem as a part of the construction industry, and to seek to use scientific knowledge for new and better methods of construction such as the use of new materials and equipment, prefabricated houses or group-building in order to improve standards and service and to lessen costs, thereby making housing more generally available. Others interested or occupied in building and the public generally, probably look upon it in this light. The sociologist has demonstrated that defective housing is inextricably associated with many human ills and for which he has instituted many welfare enterprises. Philanthropists have donated wealth for better living conditions. Life insurance companies are interested in housing as an investment. Government has entered the field of slum removal and substitution of standardized good housing construction, probably for a number of reasons. It is recognized that housing is not only a question of great and far-reaching importance, but that it is involved with social, economic, business and political affairs and that no adequate answer has yet been found for it.

The elimination of housing deficiencies apparently is not to be found by treating them as an isolated problem, but in the appraisal of their relation to general industry and to government, upon both of which they depend. But the housing problem is indicative and representative, and its study is suggestive of possible partial solutions of more comprehensive economic and political problems which must be met and mastered before adequate national housing can be achieved.

Attention was first called to inferior housing conditions in New York City in 1834 when their relation to high death rates was shown. In 1842 the health officer of that city, Doctor Griscom, demonstrated the association of epidemic and endemic diseases with areas of bad housing. After a number of surveys the first tenement house law was enacted in 1867. In 1901 this law was completely revised and a tenement house department established. Chicago's tenement house law was enacted in 1902. Other cities and states followed the lead of New York and Chicago, and many careful surveys of the evils associated with bad housing have since been made. High death rates, juvenile delinquency, crime, social unrest, class hatred propaganda—all have been shown to be associated with the bad housing areas of the cities. Originally the interest in poverty-ridden people was entirely philanthropic, but it has slowly been made evident that a community-wide economic problem is present and that *its* solution is necessary in order that the problem first considered entirely philanthropic can be solved. The present discussion is from the economic standpoint.

MAGNITUDE OF HOUSING AND CONSTRUCTION INDUSTRY

From 15 to 20 percent of the thirty-odd million families in the United States are able, because of their economic status, to choose the type of house in which to live; the resources of modern science and art are at their command. The other 80 to 85 percent are largely confined in their choice to existing buildings which may or may not include the essentials of good construction, sanitation,

lighting, heating and adequate space. More than one-third of our families now live in substandard buildings, a total of approximately forty million persons.

The magnitude and character of the housing and construction industry is such as to make it a very important factor in the economic welfare of the nation. In estimating economic status various indices are used. Among these are estimates of the total national income and partial national incomes assignable to several classes of commodities and services. No one standard method

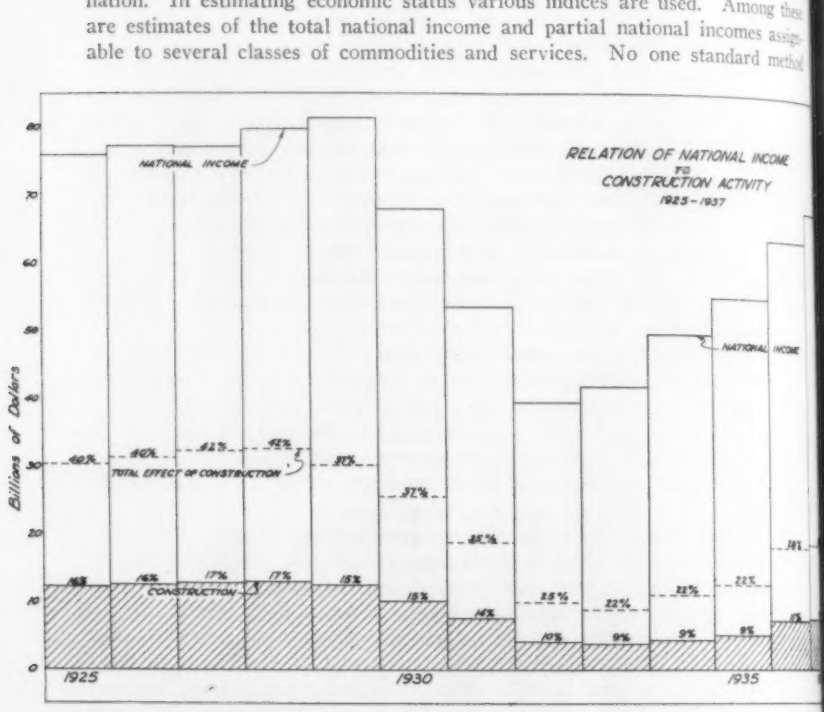

FIGURE 1

of estimate exists; various elements are included or excluded or the basis may be either an income paid out or income produced, with varying estimates resulting. No high degree of precision can be attached to the figures, yet they are sufficiently accurate for many purposes. These estimates fluctuate similarly but not always to the same extent. They appear sufficiently accurate to enable a reasonable *comparison* of the quantities involved.

A. Figure 1 shows the relative contribution of the construction industry to the national income from 1925 to 1937 inclusive. Mr. Wm. Stanley Parker, chairman of the Construction League of America, in an article in the *Engineering News Record* points out that the primary income used for construction results in secondary income used for consumers' goods and services, which is variously estimated at from one to two times the primary expenditures. By

examining these figures and assuming the secondary income as one and one-half times the primary, the proportion of national income in 1929 due to construction was thirty billion dollars. By 1933 the income due to construction had decreased by twenty-one billion and the total by thirty-one billion. That is to say, 60 percent of the loss of national income from 1929 to 1933 was due to the *decline* in construction activity and 40 percent of the recovery since 1933 has been due to *recovery* in construction activity.

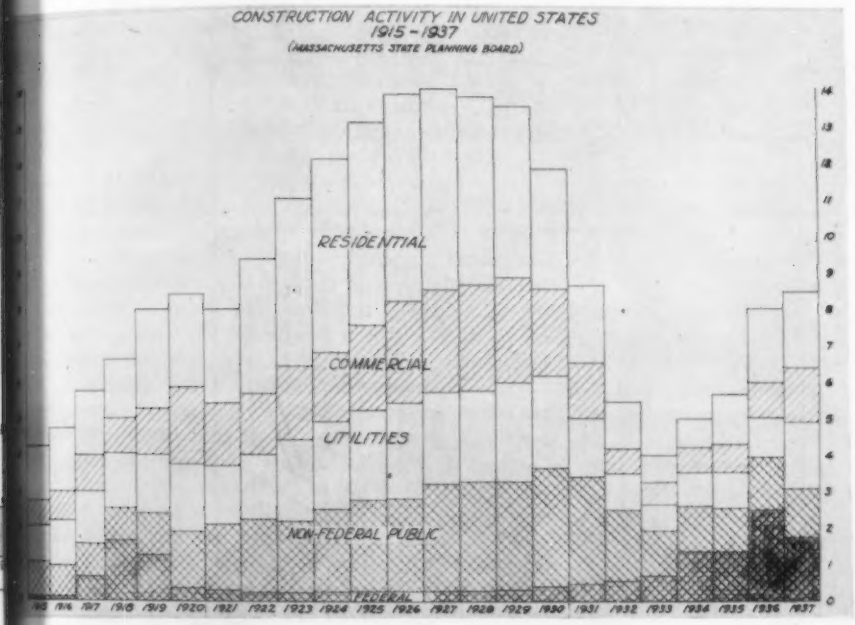
CONSTRUCTION ACTIVITY IN UNITED STATES
1915 - 1937
(MASSACHUSETTS STATE PLANNING BOARD)
RESIDENTIAL
COMMERCIAL
UTILITIES
NON-FEDERAL PUBLIC
FEDERAL
1915 1916 1917 1918 1919 1920 1921 1922 1923 1924 1925 1926 1927 1928 1929 1930 1931 1932 1933 1934 1935 1936 1937

FIGURE 2

B. Figure 2 presents the elements making up construction activity from 1915 to 1937, dividing public works into federal and non-federal, and private works into residential, non-residential and utilities. We find a number of significant facts; from 1915 to 1930 inclusive, the average annual amount was ten billion dollars, from 1930 to 1937 inclusive it was six and one-half billion dollars. In the first period public expenditures accounted for 25 percent of the total, and in the second period for 45 percent of the total. Expenditure for residential purposes was 36 percent of the total in the first period and 2 percent in the second. So far as housing is concerned, while the national income decreased 50 percent, expenditures for housing decreased 70 percent. Food, clothing and automobiles apparently have precedence over shelter. For three years, 1932 to 1934, inclusive, new housing was less than the loss from fire, flood

and demolition. If we take the deficiency in housing construction as two and one-tenth billions annually (which is the difference in the average from 1915 to 1930 and that from 1931 to 1937) there was a total deficiency of fourteen and seven-tenths billion accumulated at the end of 1937 and this accumulated deficiency is largely in housing for those in the upper one-third of the income

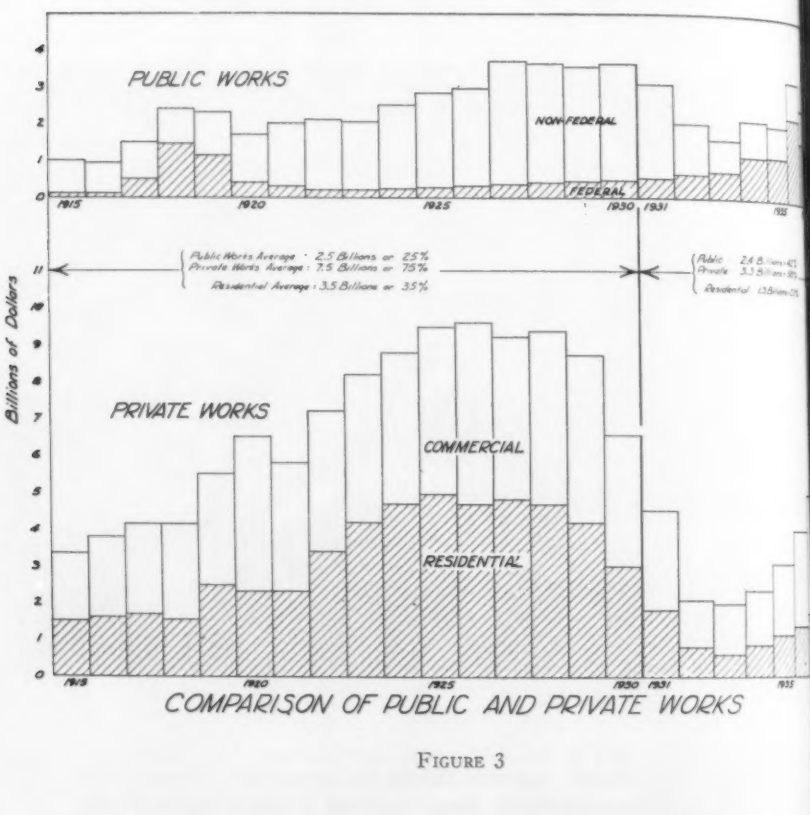

FIGURE 3

C. In Figure 3 the great fluctuations in privately financed construction are compared with the comparatively steady rate at which public works have progressed before and during the depression.

HOUSING IN LOWER INCOME GROUPS AND FEDERALLY FINANCED HOUSING

Interest in the housing problem centers largely in that possible for the people in the lower income group, two-thirds of all the people. Surveys by various agencies indicate that eleven million families are now living in sub-

standard housing units. Their average annual income is about $700. If the house should cost twice the annual income, which is the amount generally accepted as most practicable, the housing of the lower income group, which is necessary in order that all should enjoy decent living conditions, would cost twice their average annual income of $700 multiplied by eleven million, or fifteen and one-half billion dollars.

It is true that in the southern states where full basements to houses are unnecessary and where protection against cold weather is of minor importance, that a satisfactory house may, in some surroundings, be built for $1,400, if built in large groups. But this is not true in the northern states where the cost of building is higher and where more substantial housing is necessary. Housing in the city is more costly than in rural areas. The United States Housing Authority is now engaged in housing projects which cost from $3,500 to $7,000 per family unit. It is probable that the average cost of adequate housing would be around $3,000 per unit, and the total cost of adequately housing the low income groups would be somewhat over thirty billion dollars. If to this sum we add the fifteen billion dollars of deficiencies in higher class housing due to depression economies, it is seen that there is a human need for over forty-five billion dollars investment in housing in the United States.

Residential construction is now going on at a rate between one and two billion dollars annually, including that federally financed. Practically none of it is available for the millions in the lowest income groups. The federal government recognizing that a housing need, and particularly that a need of slum elimination and substitution of adequate housing in the cities existed, has taken action. First, through the N. R. A. and then through the P. W. A. it expended about one hundred and twenty-five million dollars, then in 1937 passing the Wagner-Staagal Act, it created the U. H. H. A. armed with an appropriation of eight hundred million dollars. The U. S. H. A. has built several projects and has a large number contemplated or in the course of construction. The method of financing construction is through cooperation with local housing authorities established by state legislation. The federal government advances as a gift 90 percent of the cost and the local government 10 percent. Bonds are issued and retired over a period of sixty years by federal and local contributions. There are no taxes, but the federal government contributes a fixed sum for local public services. The rent charged for such units is consequently for operating charges only, resulting in reducing rents to about one-half of that necessary if the project were privately financed with a 4 percent return on investment. One of these projects at Red Hook, Brooklyn, now under construction, is being most excellently built of all masonry, fireproof, brass piping, steel windows, elevators, landscaped, and probably good for a life of 200 years. It is costing about $5,000 per unit and the corresponding rent will be about $300 annually and is representative of the average costs of the U. S. H. A. housing. In order to live in such a unit the family should have an annual income of at least $1,350. This figure is important, because there are in the United States according to the 1935-1936 survey of the National Resources Committee, 16,000,000 families with a lower income than $1,350. It is obvious these are the ones now occupying the areas of poor housing and the slums, that

they cannot pay for the U. S. H. A. housing even with the subsidy, and wh
pushed out of the slums eliminated by the new housing must seek for oth
slums, of which there are plenty.

It is the families above that economic level who must occupy the ne
quarters, unless the federal government makes an additional rent subsi
However, there is some net gain when slums are eliminated and replaced b
good dwellings and standards of good housing are established. The feder
and local subsidies are being paid at the expense of the general taxpay
(which means an eventual burden upon the very poor as well as others)
an economic group not particularly in need of help.

From these figures it is evident that the only private capital which may b
expected to be invested in housing for the very poor is that which will
completely donated and which under present economic conditions is not availab
in the large amounts needed.

It is also obvious that a federal program proceeding at the rate of thr
hundred million dollars annually would take 100 years for completion, or if th
program were speeded up, to take ten years, a three billion dollar expenditu
annually would be necessary, which, in view of the already heavy federal budg
deficiencies, does not seem possible until a substantially increased nation
income, not now visible, is assured. If the lowest income groups were plac
in these buildings, the government would be obliged to pay rent subsidy
addition, which would add still another two billion to its annual expenditure
if all were accommodated.

Nevertheless, it is possible that true national economy demands that the
deplorable housing conditions be appraised at *their true* cost and the proble
be adequately dealt with.

THE CONSTRUCTION INDUSTRY

One possibility in the situation lies in the construction industry itself. Th
federal government, so far, in the efforts to relieve economic distress has, asi
from direct relief, turned mainly to vast and varied projects of construct
such as municipal public works, river improvement, water power projects an
housing, as the most obvious means of combating unemployment. While so
projects have been hurriedly undertaken without sufficient consideration o
their enduring value, many have been economically and socially constructiv
They have been more costly than is necessary because the construction indust
is one of the most wasteful in the whole category of industry. It is inefficie
because of lack of coherence and coordination of its parts; the various elemen
represented are not organized in such a manner that they can jointly engage i
promoting their common interests. Architects, engineers, contractors, sub
contractors, manufacturers, jobbers, retailers, financiers and labor unions a
each devoted to the short-sighted policy of getting the most for themselves ou
of whatever sporadic projects may appear from time to time.

If these various elements could be brought to see that their *individua*
interests would be best served by the promotion of their *common* interests a
that one of the reasons for the low status of their industry is that the consum
gets more for his dollar in such competing industries as automobiles, amusem

and many kinds of consumers' goods, competitive instincts might be directed against external rather than internal rivalries. This situation has been recognized to some extent but no one element in the industry seems to be suited as the agency by which such consolidation might be effected.

The public interest is so greatly affected by unemployment and the need for construction is so great, that it is possible that the construction industry in some of its divisions should be regarded as a *public utility*, in which case the government would be involved. If research should indicate such a view to be sound and that a practicable operating method could be found which would be in the public interest, progress would have been made toward good housing.

If by some means this industry with its many and conflicting interests could be transformed into a pattern corresponding to that in a great manufacturing industry where the lowest cost of the final product consistent with the quality is the main objective, the total costs of building would be greatly reduced, individuals and corporations would find that their dollar spent for construction would buy values comparable to those obtainable by dollars spent for clothes, automobiles and other more perishable goods. A revival of construction would begin. If it were possible by some means to secure a full revival, eight or ten billion additional dollars annually would be directly employed in construction, with a possible effective addition to national income of from twenty to twenty-five billion dollars. Various attempts to revive the construction industry are being made by such organizations as the Construction League of America and

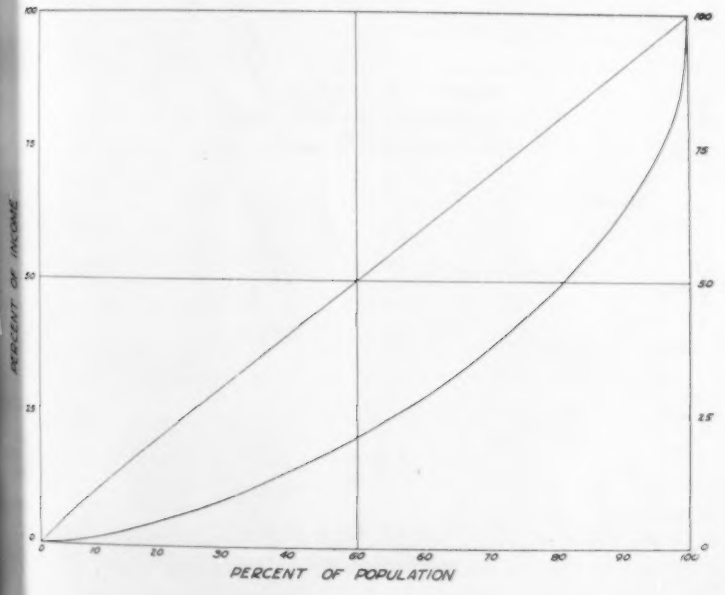

FIGURE 4

by certain manufacturers of building materials, one of whom has organized a system to partially remedy the existing condition by the creation of what is known as "Housing Guilds."

But the problems of housing and construction are so great that they apparently can be solved neither by government alone nor by industry alone. *If they are to be solved at all it must be by cooperation between government and industry.* Natural resources are available, capital is mobilized, and scientific resources are available, but cannot be used until the *human* resources of the nation are made available through the development of a consciousness of the essentially common economic interests running through all economic levels.

DISTRIBUTION OF NATIONAL INCOME

If one were to take the distribution of the national income as accepted by the National Resources Committee and make a graph as shown in Figure 4, with the vertical scale indicating the percentage of individual income and the horizontal scale showing the percentage of families and individuals receiving

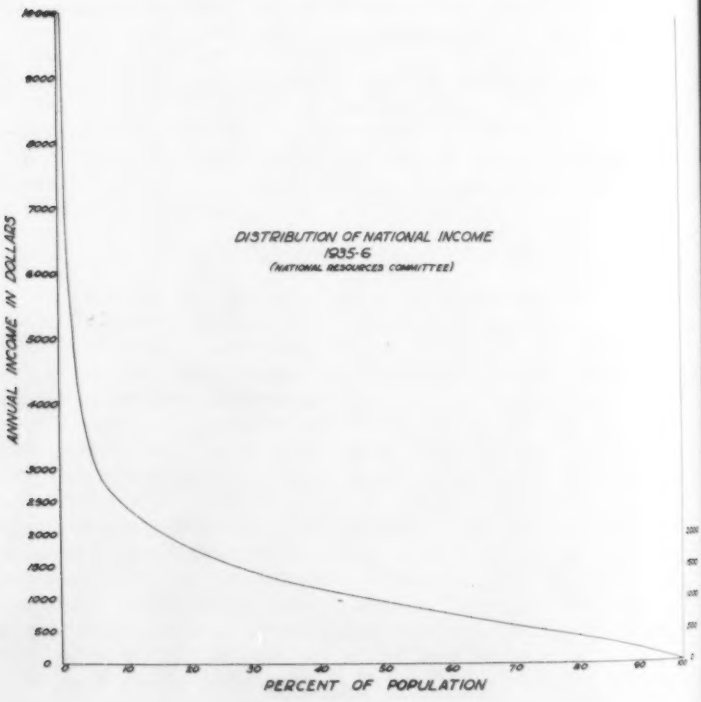

FIGURE 5

the income, it will be seen that 50 percent of the families and individuals receive 20 percent of the income and that the other 50 percent receive 80 percent of a total income of sixty billion dollars, as of 1935-1936.

If we now arrange the incomes in order of their amount (Figure 5), showing the amount on the vertical scale, and placing the largest on the left, grading them to the lowest on the right, we have a curve which shows that the median income is about $1,000, that is, that 50 percent of all incomes are larger and 50 percent smaller than this amount. The average of all incomes is almost exactly $1,500, ranging from zero to three million dollars. This type of graph, usually called a frequency curve, is used quite generally in the discussion of statistics.

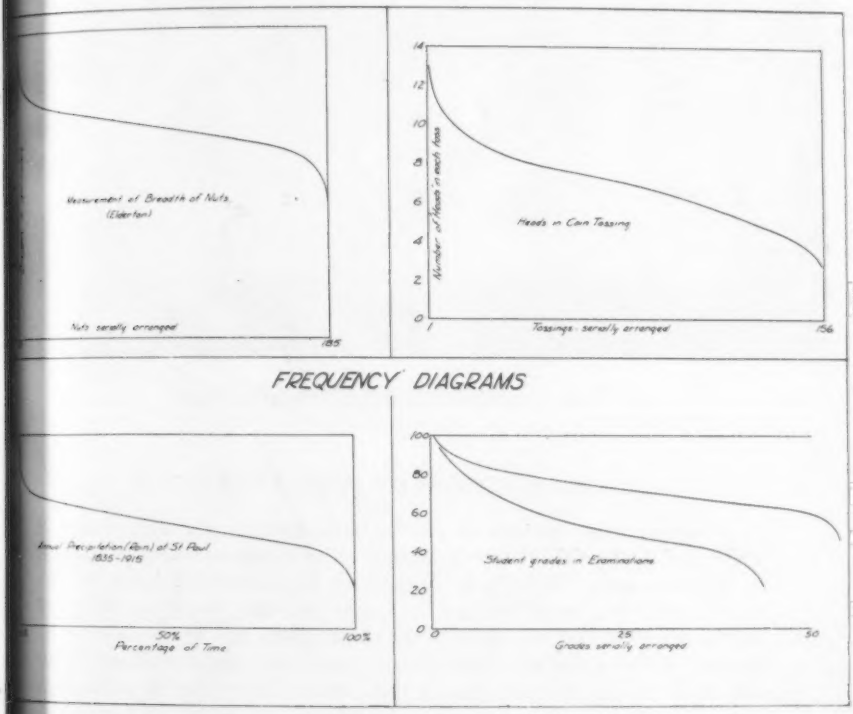

FIGURE 6

CHARACTERISTICS OF FREQUENCY CURVE

At this point I should like to digress for a moment in order to describe some of the features or characteristics of the frequency curve as applied to the comparative measurements of a large number of individual characteristics of

objects, inanimate or animate. This curve illustrates what is sometimes called the "law of averages" or more aptly, the theory of probability. It embodies principles which are fundamental in science. The vast business of insurance is based upon it. Many industries use it. In general this form of the frequency curve, whether applied to measurements of the heights or weights of individual persons, of blades of grass, to length of life, to precipitation of rain, or *to human abilities as measured by examination or by other means*, persists in a characteristic "S" shape as shown in Figure 6.

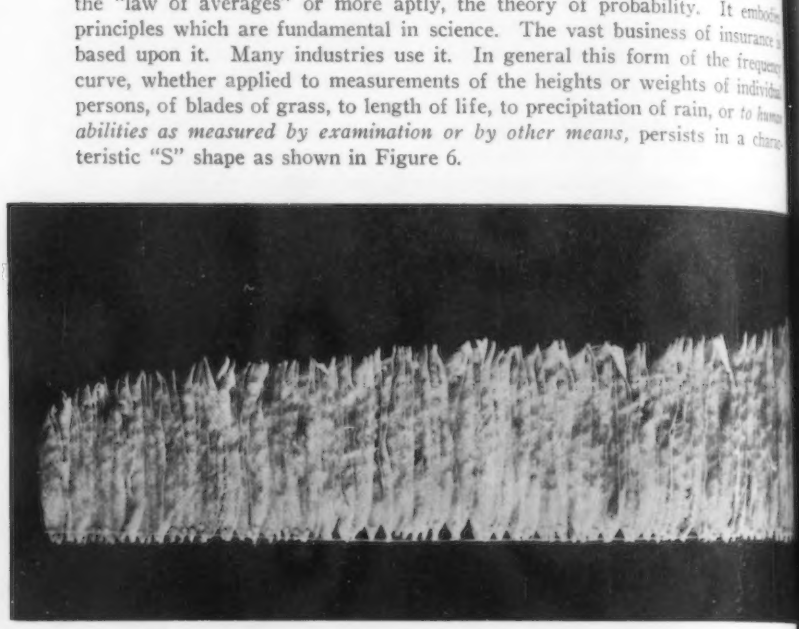

FIG. 7. Peapods arranged in order of length.

OTHER EXAMPLES OF FREQUENCY CURVE

There are other methods of plotting measurements and many methods of analysis of the special characteristics of a series of measurements which cannot be elaborated here. Whipple, in his work on Vital Statistics, defines the curve as follows: "It is a curious and important fact that if we measure natural objects, we shall find that most of the observations will be very close to the mean of all, that a few will differ from it considerably and a very small number will differ from it very greatly—in fact, these relations are so regular as to amount to what may be called a law of nature, a sort of natural frequency."

With this tendency in nature established, and knowing that it applies to human abilities and aptitudes, one would be led to believe that if the potential economic value of the individuals of a nation were arranged serially, as representing potential earning ability, a similar curve would result.

The striking characteristic of the curve of actual distribution of incomes of families and individuals is that it *does not* in its *lower ranges* follow the law of nature described.

Figure 8 is presented to indicate the curve of actual distribution of incomes as compared with a random distribution curve of the usual type.

If the average family were adequately housed, fed, clothed and provided with a minimum sum for health and recreation, its income should be, according to sociological authorities, from $1,500 to $2,000, somewhat more in the north and less in the south, more in the larger cities and less in the smaller communities and rural areas, because of corresponding costs of living.

It is also recognized that there is a considerable number of families that have little or no earning capacity and that these amount to from 5 to 10 percent of the total——those who must subsist on the earnings of others.

If we now superimpose upon the frequency curve of actual income, another frequency curve constructed so as to conform to a natural distribution of potential earning capacity, the second curve should show a *large* number of families clustering about the mean value and differing little from it, and a *small* number of families in the lowest values; those capable of earning little or nothing. There is at present no way of determining accurately the actual potential earning capacity of any individual or of determining the value of his services to society, but if we assume that the average income of the families that can and will

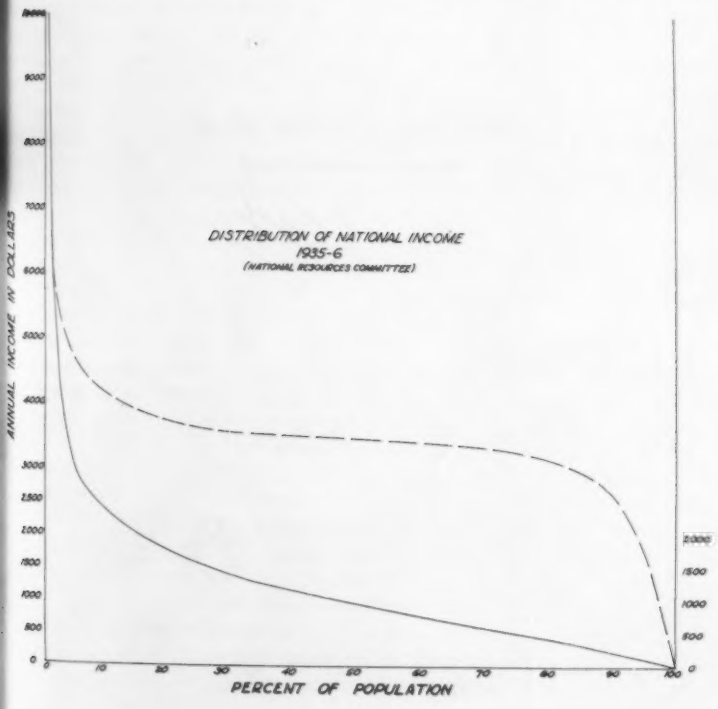

FIGURE 8

work, should be equal to the minimum necessary for normal living conditions we would set the average annual potential earning capacity of the present low income group at $1,500 to $1,750. Having made this assumption, we have a point through which it is *reasonable* to draw the second curve. The area between the curve of actual incomes and the curve of potential earning ability will roughly indicate the total annual present deficiency in national income within these groups or the amount which they must earn in order that they can maintain those conditions of decent living which they should have in a democratic society.

For the families with no income, an annual subsidy of from two and one-half to three billions is necessary. For the 80 percent of the families now below

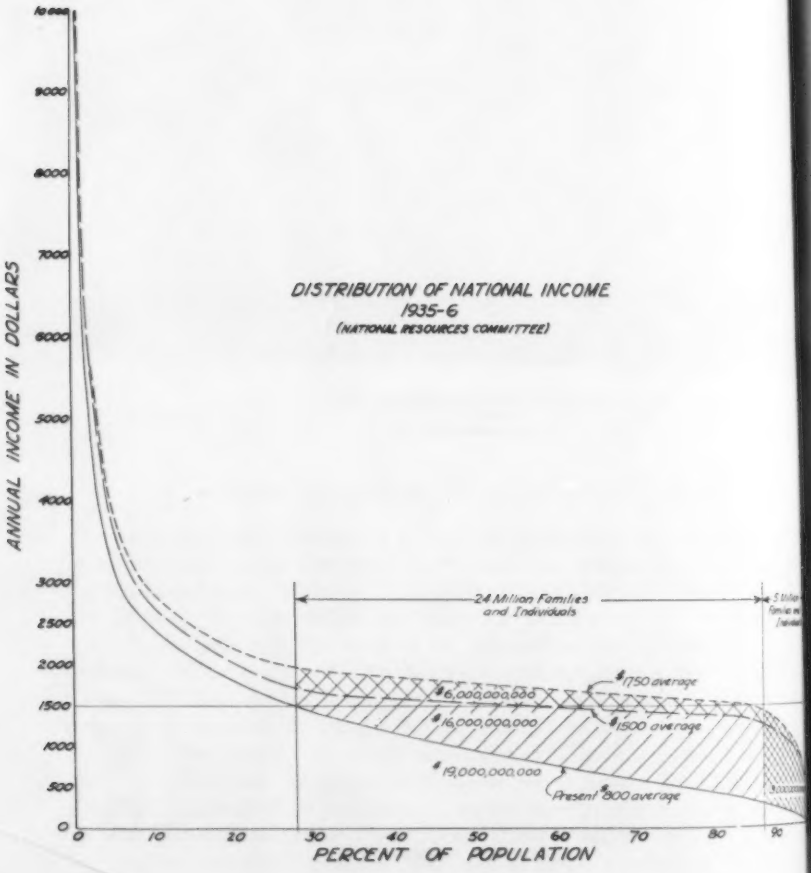

FIGURE 9

$1,500 annual income to be raised to an average of $1,500 annually would require an increase of sixteen billion dollars in annual income; if this average annual income were increased to $1,750, it would require an additional six billion dollars, or a total annual increase of twenty-two billion dollars. Also, if the earnings of the upper 20 percent were to be maintained at the same ratio to the lower 80 percent as now prevails, these figures would be doubled. That is to say, that if the average income of the lower 80 percent of the income earners were to be raised to $1,500, the total annual national income must be raised by thirty-two billion dollars, and if their average income were to be raised to $1,750 the total national income must be raised by forty-four billion dollars.

CONTINUING SUPPORT FOR HOUSING IS NECESSARY

This approach to the problem of a national income adequate in magnitude and so distributed as to provide economic opportunity for normal living for all, is used because it conveniently shows the size and character of the income adjustment problem involved if adequate living conditions and adequate housing are to be provided for the nation. It indicates the millions of human beings existing at lower economic levels, now deprived of contributing to their own and the nation's welfare. It is also used because it suggests that if the actual distribution of income followed more nearly the natural law of distribution applicable to human qualities, in this case, *potential earning ability*, the penalties we all suffer from economic instability might be alleviated. The figures presented concerning the magnitude of the housing problem indicating a housing need of forty-five billion dollars also indicate that without an increase in national income of the order which has been described, not only would it be impossible to finance the cost of construction, *but what is equally important, it would be impossible to meet the annual costs of housing or to maintain the standard of living among the occupants corresponding to the housing standards.* Adequate and successful housing means not only a good house, but a way of living and a standard of living reflecting that of the house itself.

Any attempt to solve the housing problem by either government or private means separately, *under present conditions* can at the most only *demonstrate* the character of desirable housing and its cost; it cannot cope with the entire task. The problem of housing appears to be representative of many aspects of community welfare; but by simply providing adequate housing all of the evils associated with inferior housing will not be eliminated. Furthermore, if forty million persons are moved into good living quarters, some provision must be made for them to maintain themselves at the higher level rather than to expect the ten million families at upper economic levels to keep them there. *If some provision is not made for these families to maintain themselves, any housing project large or small will fail to accomplish results commensurate with the effort made to provide the housing.* The effort to provide the housing may be lessened to a small degree by economies in construction and to a great degree by the consolidation of the many separated interests in the construction industry. However, whatever gains are made will soon be lost unless some comprehensive plan is prepared to make them permanent.

NECESSITY FOR UNIFIED POLICY AND ACTION

The success of the housing idea along with its associated benefits must rest upon the development of conditions which will make it possible for the lower income groups to secure employment by which they may continue to live on a plane affording them an opportunity for health, housing, clothing and food and recreation necessary for a normal life.

The conditions which will make employment of men possible and which will also make the employment of capital possible must be preceded by the recognition of the *magnitude* of the economic problem in which the fortunes of people at all income levels are inseparably united, and by the recognition of the fact that it is possible of solution only by unified effort.

In the face of a situation where governmental indebtedness is steadily increasing without prospect of avoiding further indefinite increase, where various groups of citizens are each hopeful that by some favorable but undefined circumstances its particular status will be improved regardless of the others, where three-fourths of the people vaguely sense the fact that they are deprived of the exercise of their potential earning power and consequently resentfully engage in labor disturbances, where government and industry are mutually distrustful, each hoping for economic dominance, *some new understanding is required* of the necessity for the pooling of resources and effort in a world where the operations of government and industry have become increasingly complex and extensive.

It appears to many that all of the reasons for the improvement of our domestic economy possess additional weight when it is considered that the nation is confronted with external conditions of economic, if not military rivalry of increasing intensity. It is perhaps not impossible that if a comprehensive program of economic defense is *not* inaugurated and followed and if the various groups with conflicting ideas cannot see the necessity for uniting to further a reasonable economic policy based on common interests and natural law, then no solution of the housing problem will be reached until the concentration of available national resources, including human resources, is effected under *compulsion* by a government of a character not yet seen in America.

History indicates that in all ages when superior economic devices appear, men eventually adapt their customs and institutions to them. In our times, science has rapidly made an unprecedented multitude of new economies possible in many departments of life, to which our customs and institutions are in process of adjustment. The economies and adjustments both are highly complex and powerful as well as numerous, and require the highest intelligence and integrity in their guidance, if violence is to be controlled and averted. This nation has other and more insiduous enemies than those which may be termed military. They reside in those groups of men who, through fear, ignorance or distorted vision, arrogate to themselves domination over our human and economic resources, unable or unwilling to identify their own welfare with that of the nation. Eventually they are destined to disappear, for the full concentration and utilization of national resources under the highest available intelligence is a *superior economic device.* It may appear in the form of governmental compulsion as it has in recent years in the totalitarian nations, with the disappearance of individual liberty. If a democratic nation is to remain democratic it

must accept the fact that in time of stress the institutions of both government and industry must likewise be centrally controlled. However, by foresight, central control may take the form of voluntary cooperation through the agency of educational processes.

EDUCATION FOR NATIONAL DEFENSE

The United States, not a military-minded nation, has found it necessary and practicable to establish military educational institutions, whose students, selected without regard to their economic status but with respect to their intelligence and fitness, are held firmly to high standards of scholarship and integrity. At West Point and at Annapolis no one escapes the discipline and environment that never fails to impress upon him the need for consideration of his fellows and, above all, devotion to the welfare of his country. The graduates of these institutions have, for more than a century, accumulated a record of technical efficiency, integrity and undoubted patriotism. All of us place implicit faith in these men. We place the military defense of our nation in their hands.

The success of our national *military* institutions indicates the desirability of a specific form of education for the *economic* defense of the nation; one which will find realization in an institution whose major objective will be to develop a national recognition of the essential economic and social interdependence among all groups and individuals without respect to economic level or walk of life. To reach its objective, this institution must enlist students of the highest qualifications. It must require high standards of scholarship vitalized by social intelligence and understanding. Its graduates, because of their superior qualities, will, by gradual infiltration into positions of influence in the nation's work and affairs, constitute the pioneer forces which will ultimately serve to guide the inevitable processes of adjustment within the pattern of democracy, forestalling the violence of compulsion by a continued educational effort, vigorous and intensive, extending into the years to come.

CONCLUSION

In conclusion, it may be said that the house and its environment have been so immensely improved by the use of scientific knowledge that today the family at, or above the average economic level, can live with greater convenience and comfort than could the most affluent of a century ago.

By considering housing for those families at the lower economic levels, a problem of great magnitude is found, the solution of which is demanded of the oncoming generation. No *adequate* solution appears within the technical fields of engineering and architecture, nor does it appear simple or direct; it is bound inseparably together with other and more far-reaching problems of human welfare. In order that the benefits of a successful solution shall be perpetuated to succeeding generations, we must first extend our concept of the educational process to a plan designed not only to call forth intellectual power but to consciously and insistently direct that power to the task of forging our many warring groups into a single instrumentality devoted to national welfare. With the success of this measure good housing for the multitudes will appear as a symbol of progress, progress won by science.

"SCIENCE IN PROGRESS"

TEN RECOGNIZED LEADERS IN THE PHYSICAL AND BIOLOGICAL SCIENCES HERE DESCRIBE THE METHODS EMPLOYED AND THE RESULTS OBTAINED FROM BASICALLY IMPORTANT RESEARCHES WHICH HAVE RECENTLY ENGAGED THEIR ATTENTION. PARTICULAR ATTENTION IS GIVEN TO THE RELATIONSHIPS BETWEEN THE NEWLY ACQUIRED KNOWLEDGE AND THAT PREVIOUSLY EXISTING. THE LAST FEW YEARS HAVE BEEN MARKED BY UNUSUALLY IMPORTANT ADVANCES IN VARIOUS SCIENTIFIC FIELDS, BUT COMPARATIVELY LITTLE INFORMATION HAS BEEN AVAILABLE RELATIVE TO THESE NEWLY PLACED MILESTONES EXCEPT TO THE ACTIVE WORKERS THEMSELVES. THE DISCOVERIES ARE WELL-ESTABLISHED AND OF SUCH BASIC IMPORTANCE AS TO MAKE IT ESSENTIAL TO HAVE THE INFORMATION ACCESSIBLE TO ALL WHO ARE INTERESTED. THEREFORE, THIS VOLUME BASED UPON THE NATIONAL SIGMA XI LECTURES DELIVERED IN 1937-38 HAS SPECIAL SIGNIFICANCE, SINCE NO OTHER PUBLICATION HAS HAD ACCESS TO THIS MATERIAL. THE BOOK HAS NOT BEEN WRITTEN DOWN TO A POPULAR LEVEL IN AN ENDEAVOR TO ATTRACT THOSE WHO DO NOT HAVE A GENERAL KNOWLEDGE OF MODERN SCIENTIFIC ENDEAVOR, BUT NEVERTHELESS, WHILE MAINTAINING A HIGH DEGREE OF SCHOLARSHIP, THE CHAPTERS ARE INTERESTINGLY WRITTEN AND PROFUSELY ILLUSTRATED WITH STRIKING AND EXTRAORDINARILY VALUABLE PHOTOGRAPHS. HERE ARE THE "MEN AND MACHINES" WHO HAVE MADE IMPORTANT ADVANCES INTO UNMAPPED AREAS, WHO ARE IN THE FOREFRONT OF SCIENTIFIC RESEARCH TODAY.

CONTENTS

Foreword—HARLOW SHAPLEY

Atoms, New and Old—E. O. LAWRENCE, University of California.

The Separation of Isotopes and Their Use in Chemistry and Biology—H. C. UREY, Columbia University

Recent Advances in the Study of Viruses—W. M. STANLEY, Rockefeller Institute.

New Views in Virus Disease Research—L. O. KUNKEL, Rockefeller Institute.

Vitamins and Hormones—K. E. MASON, Vanderbilt University.

The General Rôle of Thiamin (Vitamin B) in Living Things—R. R. WILLIAMS, Bell Telephone Laboratories.

Hormones in Reproduction—EDGAR ALLEN, Yale Uinversity.

Chromosomes in Relation to Heredity—T. S. PAINTER, University of Texas.

Electrical Potentials of the Human Brain—E. N. HARVEY, Princeton University.

Animal Metabolism from the Mouse to Elephant—F. G. BENEDICT, Carnegie Nutrition Laboratory.

THE PRICE OF THIS VALUABLE ADDITION TO MODERN SCIENTIFIC LITERATURE IS $4. ALL PROFITS ACCRUING FROM ITS SALE ARE ADDED TO THE SOCIETY'S RESEARCH FUND. ORDERS SHOULD BE SENT TO THE NATIONAL SECRETARY.

LITERATURE AND SCIENCE

ROGER PHILIP MCCUTCHEON
Tulane University

The plight of a humanist in a circle of distinguished productive scientists is perilous, if not pathetic. He must first congratulate the group on their splendid achievements which have so valiantly extended the frontiers of knowledge; achievements whose titles he dares not try to pronounce. He must express the pious hope that future discoveries may be even more impressive and unpronounceable.

In the next place, it is his duty to deplore the separation of our fields of knowledge to so wide distances that a humanist no longer understands a scientist, and scientists themselves no longer speak a common language, except in so far as the results of their work may be stated in complex and dubious mathematics. Just here he recalls Mr. Kittredge's definition of a pedant: a man who uses a technical vocabulary not your own. He should next deplore excessive factual and hand-minded approaches to truth, and become evangelical and perspiring in a plea for a more humane approach. He can also be counted on to deplore the way in which our information and our techniques have run so far ahead of our ethics, that the human race is now embarrassed to have at its disposal miraculous powers which it has not yet shown itself worthy to possess.

The Society of the Sigma Xi represents an interest of the utmost significance, the only interest, in my opinion, which can justify the application of the name "university" to an institution of learning. Creative scholarship is not an activity which is recognized by the cheering sections; it does not frequently make the first page of the Sunday papers; not many of the students in colleges and universities know that it is going on. But its presence in an educational institution remains a precious, indispensable ingredient. Like others of our finest cultural possessions, it deserves more cherishing than it receives; yet, happily, it is a hardy plant, able to endure the chilling winds of official neglect, and surviving long dry spells miraculously. But it thrives best with encouragement and attention.

The topic, literature and science, attracts me irresistibly. With one of these terms I may claim some acquaintance. My ignorance of the other will shortly be demonstrated. I am remembering that in the nineteenth century Professor Child of the Harvard English department once told the faculty that of course no scientist could ever appreciate literature. Whereupon Nathaniel Shaler, the geologist, asked, just what branch of English literature would a scientist have the most difficulty in appreciating? Child, after brief reflection, suggested that the Elizabethan drama would likely offer the most serious obstacles to the scientific intellect. Shaler thereupon read a mass of Elizabethan plays and, the more fully to refute Child's suggestion, even wrote some Elizabethan plays by way of lagniappe. I am, therefore, not going to tell you that you cannot appreciate great literature. One might recall also that in the same period of Shaler's triumphant assertion of scientific abilities, a young southerner entered

Harvard. His advisor said to him, I see you are down for history and English and Shaler's geology. Better take Charles Eliot Norton's course in Dante and get the bellyache view of the universe, by way of antidote.

Perhaps a retrospective glance at some phases of our cultural history may provide a less astringent introduction than Norton's course in Dante. I propose to examine, very briefly and imperfectly, to be sure, the relations between literature and science as they existed in the seventeenth century, again about the year 1800, and end with some observations concerning the present.

The phrase "climate of opinion" has come to have a great fascination for me. The ideas regnant at any one time frequently seem to fall into patterns; too much can easily be made of such manipulations, I am well aware, but the exercise is a stimulating one. For example, is it merely a chronological accident that in 1492 three separate activities, each of great human consequence, were under way? Columbus was questing to his new world just at the same time that Erasmus was taking his priestly vows and beginning his voyagings in church history. Within the same few months, Aldus Manutius was opening his printing shop in Venice, and preparing to publish those famous editions of the classic writers in which the minds of all Europe were to go exploring. Again, just at the time when Newton and Descartes were explaining the universe in terms of regularity and precise mathematics, regularity entered into English poetry in the form of the rhymed couplet, and continued in possession of English poetry until the coincidence of the political revolutions in America and France with the romantic revolution in literature made more spacious and unpredictable forms available.

In the middle of the seventeenth century, as it happened, men of letters and men of science still spoke the same language, and indeed stimulated each other's activities. The very founding of the Royal Society itself was hastened by proposals from men of letters. Everyone knows that the scientific developments of the seventeenth century owe much to Bacon, a debt universally acknowledged if not completely understood. Also, the movement towards science received some impetus from the great Moravian educator Comenius, who, as early as 1632, was writing that "as far as possible, men are to be taught to become wise, not by books, but by the heavens, the earth, oaks, and beeches; that is, they must learn to know and examine the things themselves, and not the observations and testimony of others about the things. Science is the more certain the more it rests upon sense." Comenius was so much impressed with the soundness of his method that he subtitled his book, *The Great Didactic*, "a universal system for teaching everybody everything," which I suppose we must regard as a literary rather than a scientific utterance.

The Civil Wars in England, which broke out in 1642, did not prevent certain choice spirits from continuing their interest in scientific education. The famous "invisible college" at Oxford in the late forties and fifties, as you know, largely moved to Gresham College before 1659. John Evelyn, known to some of you as a memoir writer whose accounts provide an interesting parallel and check to the more intimate diary of Pepys, and known to others of you as important in sylviculture, wrote to Robert Boyle in September, 1659, of his wish to found a retreat for scientific studies. Evelyn's plan involved a common dining hall

and library, with small dwellings for the members of the society; "all of which should be well and very nobly furnished, for any worthy person that might desire to stay any time, and for the reputation of the college," a hint still needed by some college administrations. The plan further involved a rigid routine of study broken by daily conversation periods which were not to be omitted save in times of sickness. Each Thursday there was to be a musical meeting. "Every person in the society shall render some public account of his studies weekly if thought fit," reads another provision. By way of exercise, bowling was to be permitted, and everyone was to cultivate his own garden, a phrase which is curiously prophetic of Voltaire's *Candide*. The promotion of experimental knowledge was to be the principal aim of the institution.

Abraham Cowley, at the outbreak of the Civil War, had been a minor literary man, with ambition to write a great epic poem. His ambition was in excess of his talent; we remember him today as a verse-maker of interest and distinction, but not as a truly great literary artist. He was also a physician. He tried a play or two, popularized Pindaric odes, and wrote charming essays. One of them has the engaging title, "The Dangers of an Honest Man in Much Company." This subject may have been suggested to him by his acquaintance with the scientists of the Royal Society. Probably stimulated by Evelyn's letter to Boyle, Cowley drew up his Proposition for the Advancement of Scientific Knowledge in 1659, and printed it in 1661. On the chance that you will find it amusing, if not instructive, I venture to summarize it:

Cowley thought that the universities were still so much under the spell of Aristotle that they were not inquiring into the secrets of nature. He says, nobly: "We must not content ourselves with that inheritance of knowledge which is left us by the labour and bounty of our ancestors, but seek to improve those very grounds," . . . He suggested the founding of a philosophical college near London, to have twenty professors, with scholars, servants, and the like, professors and chaplain to have an annual salary of 120 pounds. He figured that at first his college would have 700 pounds a year for experimental purposes, but thought that this sum would be presently increased from the benefits to be derived from the inventions of the faculty, none of whom was to be permitted to profit solely from any of his discoveries. The college was to be governed by a chancellor, "a lover of sound learning, and no stranger to it," are his words. Ample provision was to be made for plant and animal experimentation, as well as for astronomical observations.

Of the twenty professors, four were to be always traveling beyond seas, to Europe, Asia, Africa, and America, and to report their observations. These traveling professors were to take an oath "never to write anything to the College but what after very diligent examination they shall fully believe to be true, and to confess and recant it as soon as they find themselves in error."

Among the duties of the resident professors teaching and lecturing were mentioned. Part of the public duty of the faculty was to be the exploding of popular errors in experimental philosophy. Every third year the college was to give an account of its scholarship, "in proper and ancient Latin." The chaplain had his duty strictly limited. He was to read prayers, to preach, and administer the sacraments, but, in Cowley's words, "he shall not trouble himself

and his auditors with the controversies of divinity, but only teach God in his just commandments and in his wonderful works."

Cowley hoped that the school would have about 200 students. He planned to make it free "to such poor men's sons as promise either use or ornament to the commonwealth." Such poor boys should have every advantage, there being, he wrote, "nothing of eminent and illustrious to be expected from a low, sordid, and hospital-like education."

The first historian of the Royal Society, Sprat, gave Cowley credit for hastening the organization. His statement is: "When the members of the invisible college were thus ordering their platform there came forth a treatise which very much hastened its contrivance; that was, a proposal by Master Cowley of erecting a philosophical college." Sprat, however, objected to Cowley's idea that the experimenters should also teach. "The labour of teaching," Sprat wrote, "is not so proper for experimenters to undergo, for it would not only devour too much of their time; but it would go neer to make them a little too magisterial in philosophy than became them, by being long accustomed to command the opinions and direct the manners of their scholars." Sprat, you see, thinks that a scientist's character cannot stand the moral strain of teaching, and fears he will become dogmatic instead of remaining experimental.

Of the significance of the Royal Society itself it would be impertinent for me to speak. It served literature, however, in an indirect but important manner. Sprat tells us that the first members of the Society were determined to express themselves as clearly and succinctly as possible, and agreed to avoid all swellings and inflations of style. The Transactions of the Society began publication in 1665; by 1675 the average sentence-length of the articles in the Transactions had been shortened about fifty percent.

It is to be remembered that in its early years the Royal Society included men of letters as well as men of science. Cowley, Evelyn, Pepys, the poet laureate John Dryden, these were members, along with Boyle, Halley, Lord Brounker, Newton, Sprat, and Wilkins. At one of the early meetings Doctor Croone performed an experiment on chickens. A fowl was strangled until it was apparently dead; then it was revived by means of a bellows and a tube in its throat. Cowley and Dryden were both present on this occasion, it seems, and there is no record that the experiment troubled them in any way.

A century or so later the Royal Society had no distinguished literary men in its membership. They were on the outside, making fun of it. Had the president of the Royal Society in the last decade of the eighteenth century wished to perform again the Croonian experiment with a similar audience, he would have had to invite Robert Burns, who had apostrophised a field mouse as his poor earth-born companion and fellow mortal; William Blake, who was writing that a robin redbreast in a cage puts all heaven in a rage; Wordsworth, to whom the meanest flower that blows gave thoughts that often lay too deep for tears; and Coleridge, whose ancient mariner suffered a fiendish penalty for slaying an albatross, and who had expressed his enthusiasm for the lowly animals by addressing a jackass in the immortal apostrophe, I hail, thee,

brother! This group, one suspects, could not have endured calmly the spectacle of a scientist strangling an innocent chicken.

How can we account for this change? Specialization, of course, inevitably tends toward separation. For another thing, science had been under attack from the church and from philosophy; it had also been under attack from literary men, some of whom feared that it was destroying the mystery and the beauty of life. To be sure, it was the foremost literary scholar of the early eighteenth century, Bentley, who had done great things for science at Cambridge. He had built an observatory for the first Plumian professor of astronomy, had fitted up a laboratory for the first professor of chemistry, and had helped to found the first professorship of botany. But Hartley thought that the "vain glory, the self-conceit, arrogance, emulation and envy found in the eminent professors of the sciences" were beyond endurance. Another critic wrote thus: "Let it be remembered that a taste for science, pleasing and even honorable as it is, is not one of the highest passions of our nature" . . . . this statement, which would mean little from a mere poet, may seem even more fantastic when you know that it was written by Joseph Priestley.

There was an immortal dinner—or so the host called it—given by the painter Haydon in 1817. Wordsworth, Lamb, Keats, among others, were present. Lamb, after sufficient warming, began an attack on Newton, calling him "a fellow who believed nothing unless it was as clear as the three sides of a triangle." Lamb and Keats agreed that Newton had destroyed all the poetry of the rainbow by reducing it to the prismatic colors. Presently the company drank a toast to Newton's health, and confusion to mathematics.

It should be remembered that Wordsworth later described Newton's bust at Cambridge as: "The marble index of a mind, voyaging forever through strange seas of thought, alone," which might indicate that Wordsworth had finally forgiven Newton for destroying the beauty of the rainbow.

In general, with the very important exception of Shelley, the nineteenth century men of letters were opposed to the science of their time. Perhaps they recalled Boileau's remark that Descartes had cut the throat of poetry. So they opposed materialism with mysticism, setting imagination against sense of fact, feeling against reason. They denied that the scientific description of the world could give us the real world. They admitted certain progress in some ways, of course. They knew that plumbing and transportation were rapidly improving, but they could not agree that art and morals would necessarily also improve.

Under somewhat varied phraseology, the fundamental difference has continued. The more imaginative, romantic, mystical personalities, who require a certain area of the unknown as a necessary playground for their imaginations to wander over, regard each lessening of this unknown as one more devil's triumph. About 1880 an eminent critic feared that "owing to the special tendency toward science, and to its all-devouring force, poetry would cease to be read in fifty years." The prophecy has not yet been entirely fulfilled.

The collision of Darwin and Huxley with men of letters was not as violent with the clergy, but it was none the less vigorous. Matthew Arnold's essay, "Literature and Science," since it has given my title, shall have a brief notice here. Arnold argued first that his definition of literature would include good

scientific writing also, and that he and Mr. Huxley, therefore, had no real quarrel. But his next point was to argue from the general nature of the human race, which had a need for conduct and for beauty, that science alone could never satisfy. "For the generality of men," to quote Arnold, "when they have duly taken in the proposition that their ancestor was a hairy quadruped furnished with a tail and pointed ears, probably arboreal in his habits, there will be found to arise an invincible desire to relate this proposition to the sense in us for conduct, the sense in us for beauty."

In our own day there has been evident a new approach to this old problem. Science, far from being the enemy of beauty, has been heralded as the friend, and even the chief source for beauty. Edna Millay exclaims, in one of her excellent sonnets, "Euclid alone has looked on beauty bare," and thus pays tribute to the cold beauty of pure reason as expressed in geometry. I recall also a better-than-average recent play, *Wings Over Europe*. The hero, a brilliant young scientist, has discovered how to control atomic forces. He unlooses the atomic forces in a lump of sugar out on Salisbury plain, and the result is a hole big enough to hide Salisbury cathedral. But the prime minister and the minister of war decide that the secret is too dangerous for human society to possess. The inventor is shot; as he is dying he is heard to mutter a mathematical equation. "Do you know what that is?" says a scientist in the group around the dying man. "That's Clerk Maxwell's formula for light." We might compare this fictitious death-bed utterance with a real one. When the French writer Flaubert was in his last illness, he asked to have read to him some of St. Beauve's prose, notable, you may recall, for its flawless clarity and its resolute avoidance of sentimentality. Flaubert, too, wished to look on beauty bare.

We have been dealing, you see, with an eternal question. Perhaps it is the old quarrel between Platonist and Aristotelian, incapable of solution, since the terms in which the disputants think are too remote ever to meet. There is still work enough for us all.

Doctor Johnson was once a guest in Boswell's home, and a troublesome one he was, to be sure. He wrote a masterly letter to Mrs. Boswell afterwards, which concludes: "The only matter in which I have the honor to agree with you is, in loving Boswell, and while we are so much of a mind in a matter of so much importance, our other quarrels will, I hope, produce no great bitterness."

So, although the scientist and the humanist are doomed never to understand each other, perhaps we can respect each other's work, even each other's right to find the durable satisfactions of life in his own way. We shall do this the more readily if we agree that both truth and beauty are still too rare in our world, and deserve all the protection and encouragement we can give them. I believe we are of the same mind in this important matter.

IMAGINATION AND PROGRESS

L. O. GRONDAHL
Director, Research and Engineering
Union Switch & Signal Company

The observations here made are based on my experience with industrial development problems. I have been very much impressed with the fact that the progress on such problems is usually very slow.

We shall not try to give a scientific definition of imagination or to explain how the human imagination functions. We all know well enough that the word has its origin in the idea of image formation, and that in making our images we are usually arranging parts that are already known, either by hearsay or in our own experience. It is very difficult to imagine something that is not composed of known parts. Imagination is certainly necessary, and is applied in all fields of human activity in which there is any attempt at progress into better conditions. This applies to pure science, applied science, industry, economics, business, government, education, international relations, and any other field of endeavor that one might mention.

We shall think of progress as any result that increases human happiness, and especially as it produces satisfaction in accomplishment or in improving conditions of living.

It will probably be agreed that for the best results the imagination must be applied consciously, and that a definite effort must be made both to use it and to control it. Everyone knows that thinking is hard work, and something that we reluctantly indulge in. Exercise of the imagination is thinking of a kind that probably requires more initiative and more directed effort in order to be effective than any other type of thinking. In the time at our disposal I should like to try to illustrate what I think is a fact, namely, that our imaginations advance very slowly and that, since imagination is essential in every real advance, the most direct way to increase our rate of progress is consciously and persistently to stimulate its activity. Sometimes we get the impression that we are progressing very rapidly. When the progress is analyzed, however, we find that it has been slow and that we did not realize that progress was being made until we noticed some big change which may have taken a long time to materialize. One reason for slow progress is that our imaginations are not usually, probably never, able to make very large jumps, but proceed in very small steps from one idea to the next by adding or subtracting some small element. I believe that our rate of progress could be enormously increased if imaginations could be stimulated as they have been in some periods.

Invention is usually thought of as being applicable mostly to physical phenomena or physical accomplishments. It is undoubtedly one of the most important activities of man, and should be thought of as being applied to all fields. It is applicable and just as important, possibly even more important, in pure science than it is in applied science, and it is certainly a mistake to think of invention as applied only to physical problems. Inventions in govern-

ment, in economics, and in social relations generally are certainly of the highest importance and require the application of imagination to just as high a degree as does invention as applied to physical problems.

It is stating the obvious to say that imagination and invention are necessary in music, poetry, painting, and sculpture, and those fields will not be discussed. Some of us think that in some of these fields too much imagination has been used, and since an after-dinner speech should not indulge in controversial subjects, the less said about that the better.

If we consider pure science, I suppose no one would think of complaining of the lack of application of imagination in that field. Even there, however, the progress that has been made, and during the last few years it has been very rapid, has been made in very small steps. If we consider any individual case we shall find that the imagination was stimulated by the need of a solution, which had usually been sought for a long time and by many different methods before the successful solution was proposed. The successful solution sometimes looks to the distant observer as having come practically out of a clear sky. It is usually the fact that it is the result of many years of thinking and struggling and experimenting, and that the idea has not jumped full blown from the mind of the inventor, but has grown in his mind through many months of very intense application.

The use of imagination in science is made necessary by our very definite limitations both in experiments and in thought. Nature is so complicated and so difficult to observe that adequate descriptions seem impossible. The scientist then uses his imagination and allows it to work on the elements in which he is especially interested, and to segregate them as though they were the only elements involved. On the basis of this limited field, he then invents his explanation and proceeds to try it out experimentally or theoretically to see whether it is effective in a wider field of application, which it must be in order to be really valuable.

Our difficulties result from several circumstances, one of which is our inability to see or observe the elements in which we are interested. For instance, atoms and molecules are so small that we are not able to see them directly even with the most powerful microscope, and this is a condition that we can probably never get around because of the wave length of the light to which our eyes are sensitive. When such light was the only light that was available for observations, it was nevertheless found possible to write explanations of what takes place in the physical and chemical interactions between atoms and molecules. The results obtained were certainly reached as a result of a very active and intense application of imagination and invention. The laws of chemistry were explained as being due to the interaction of particles which were called atoms. The gas laws were written on the assumption that gases were composed of elastic particles, atoms, and molecules, which behave very much like billiard balls. The gas laws written on this assumption were not entirely satisfactory, but were approximations and they were improved and made to correspond more nearly to the conditions encountered in nature by applying corrections which took into account the forces of interaction between the molecules and the fact that the molecules had volume.

Similar problems arose when the experiments of J. J. Thompson and others indicated that atoms and molecules were not the ultimate particles. From experiments in which the physicist observed fluorescent spots on glass, discharges of an electroscope, lines of heavy condensation in cloud chambers, and other phenomena, conclusions were drawn concerning the existence of electrons, protons, neutrons, etc. None of these particles can be observed directly or individually. As a result of the work with them, however, it has become possible to take pictures of the arrangements of atoms and molecules, and even of the arrangements of electrons in the atoms and molecules. However, the fact remains that the whole structure is a mental construction based on imagination and invention controlled by the experimental results.

If we consider such matters as Bohr's theory of the spectra, Planck's theory of the quantum, and the uncertainty principle, we see that in the case of Bohr's theory the inventor was brave enough to ignore entirely everything that he knew about electromagnetism and to jump to a construction and an explanation which seemed to contradict electromagnetic laws. This fitted together very well with the quantum theory of Planck, in which he ignored what every physicist knew or believed concerning the transmission of energy by wave motion. The uncertainty principle is probably more nearly a direct mathematical deduction, but also involves a great deal of inventive effort.

On account of the great distances involved, we have similar difficulties in our study of astronomy and cosmology. We observe certain spectra which do not correspond exactly with the spectra that we observe on earth, so we conclude that the universe is expanding. This may or may not be the correct conclusion, but it is the application of the same functions of the human mind, namely, invention and imagination. When we try to study origins, whether of the universe or of the details of the structure of the earth, we have to do the same thing.

Not only does the size of particles or the enormous distances involved make it necessary to use imagination, but the multiplicity of parts require the same application of ingenuity. In the case of gases, for instance, the multiplicity of parts makes it impossible to consider mathematically the reaction of the parts upon one another, and to predict from one minute to the next what is going to happen, even if we could see them and set up an initial condition. It is necessary to use statistics.

There is another type of multiplicity which is equally difficult, namely, the multiplicity of characteristics. Anyone who has studied metals, semi-conductors, plants, or animals, or human beings, or the weather, will agree that there are too many characteristics of too wide a variety to make it possible to construct any adequate theory or description that will make it possible to predict accurately the future performance of any of these entities. Human beings and the weather are both notoriously difficult.

Nevertheless, the attempt of the scientist is to construct descriptions or formulate laws as we call them which will bear a one to one relation to phenomena. Thompson, Bohr and Planck took the details in which they were especially interested and formulated descriptions which fitted the phenomena that they had observed. Later they found that the descriptions had to be

modified in order to take in other phenomena which had not been included in the original consideration, and it will probably never be possible, for instance, in the case of Bohr's theory, to introduce enough details into any theory that we are able to construct to include all the spectral characteristics of all the elements or compounds.

Before we leave this subject I want to repeat a statement that I made at the beginning, namely, that it is very difficult for us to imagine something that we have not experienced, and I believe that if we analyze the theories or the inventions that I have mentioned we shall find that they are all composed of known elements. To be sure they are put together in very unusual ways, and in ways that seem to be entirely contradictory to our previous experiences. However, the elements are not new.

Probably it is true that both in science and philosophy the most important recent discovery of all is the realization that it is not necessary in all cases to adhere to the old philosophic rules or to be circumscribed too closely by our experiences. The important thing is to construct a system that may be used for description and for prediction, and for this purpose it is only required that there should be complete correlation between our mental construction and our observations.

Einstein realized that it was possible to go farther in making such a construction if we threw overboard our usual notions about time and space, so we have the application of what are known as non-euclidean geometries. Many illustrations could be given, but it will suffice to say that the result of such considerations is the realization that natural laws are not necessarily unique existing relations in nature to be discovered by us, but that we can invent descriptions which serve the purpose of natural laws, and that the nature of the description depends on the postulates with which we begin. If we begin with our regular everyday experience and the way that we usually think of them, we have the Euclidean geometries, and the structure that we make based on that is satisfactory within certain limits. When we undertake a study of very small particles with very high velocities under conditions that have been encountered in recent studies in atomic and nuclear physics, or a study of certain astronomical problems, then the description in terms of the Euclidean geometries becomes very difficult. It becomes easier then to begin with a new set of postulates and to make an entirely new description. If it is successful, this applies to the extreme conditions and turns out to be the same as the old description when it is applied to macroscopic objects that are moving with ordinary speeds. The invention of these new methods of thought, as I said a moment ago, is probably the most important scientific and philosophic contribution of recent times.

When we consider applied science, the application of invention and imagination is quite different. Under applied science we could consider many fields, such as the applications of physics and chemistry to medicine and biology, or the application of biology to medicine and psychology. Since my experience has been in the application of physics and chemistry to industrial problems, I shall confine my remarks to that field.

We often hear it said that we need more basic science in order to have the basis for the invention of new products of practical value to build new industries so that we may employ more men and improve conditions of life generally. When I hear that statement I often wonder if it is true. Did you ever try to think of some new category of devices that would add to your convenience or your happiness, and which is not already available if we apply the science that we already know? I have, and I confess that I really do not know of anything physical or chemical that I should like to have that is not already available. We can travel as far and as fast as we like. We can talk to all parts of the world. We can listen to what is going on in all parts of the world, and with television we can even see, if we want to, what is going on in any part of the world. We can travel on the earth, under the earth, in the air, on the ocean, or under the ocean. We can go to any part of the earth that we are desirous of reaching. It does not seem to me that our immediate need is more in the way of potential physical conveniences, but that what we do need is the ability to assimilate what we already have. In order that I may not be misunderstood, I must hasten to add that of course we need all the fundamental knowledge we can get and that I am talking just now only of our most pressing immediate need. Much could be said about this phase of the subject that would lead to what I shall mention later, namely, that we just now need the application of imagination and invention more to the use of the things that we have than to the making of more or better things.

This condition reminds me of the story of the farmer who was approached by a government agent, and urged to attend a farmer's institute. The farmer's institutes that are conducted by the government are very instructive and very effective in improving the condition of the farms. The result of the research of the government is made available to the farmer in the particular community in which it is applicable and valuable. When this government agent had presented his argument, as he thought sufficiently effectively, the farmer thought for a moment and then said that he didn't think it would be worth while to go to the farmer's institute to learn anything more about farming, because "I ain't farming as good as I know how now." That in a word is the condition which the whole world is in as far as application of science is concerned, and illustrates one point in regard to imagination. It is not only in the scientist or in the applied scientist or the engineer that imagination and invention is essential. Practical progress is even more dependent on the use of imagination by the manufacturer, the sales organization, and by the user of the products of applied science. The manufacturer has to be able to visualize the use of the product, and the possibilities of interesting prospective buyers in the use of the product. The same is true of the sales department, and also of the user who has to be able to visualize the increased convenience to him if he uses the product that is offered. This imagination is not always present, and the applications of practical devices very often have to wait a long time on account of the lack of this imagination.

A new product usually goes through the following steps: First the inventor has some indication that he has something that he thinks is worth while. The results may be very poor, but indicate the possibility of practical application.

In the second stage the inventor has to obtain an opportunity to continue his work on his development. He has to have capital. He has to be able to stir up the imagination of the people who are able to supply him with capital, and if his invention is in an embryonic stage this is sometimes very difficult. Someone always has to be reached and influenced to the point where he is willing to gamble on the possibilities that this may be as good, or nearly as good, as the inventor thinks it is. In the third stage if he has been successful in getting some appropriation and an opportunity to work, he goes through a period of slow improvement of the device, and this period may be very long. It may extend over many years. In the next step he is able to demonstrate the limited practical value, and then he must sell the idea to someone who is able to manufacture and to promote. If he has sold it to the manufacturer, he may have to sell it again to a sales organization, and the sales organization has to sell it again to the user. When it finally gets on the market the general public gets the impression that here is something that appeared very suddenly, more or less out of a clear sky, and out of the brilliant mind of an inventor who was able to sit down and say that this is exactly how this is going to work. The general public does not know that the final result may have come about after many years, probably a life time, of effort and disappointments, and that it is a result of a very gradual, slow step by step development, in which the imagination was able to see just far enough ahead to keep the inventor and the others involved interested. I have been impressed many times with the fact that this is the natural and the usual process through which a new development goes. The human mind is not able to invent suddenly or to make long steps forward in a short time. When one looks back upon the result, it seems strange that the development should have taken so long, but I think anyone who has had contact with it will agree that the process that I have described is the natural process. This may be illustrated by the history of Alexander Graham Bell's invention of the telephone.

Alexander Graham Bell's father was a teacher of elocution in England. Alexander had two brothers, and all three finally decided to follow in their father's footsteps and become teachers of articulation or elocution. When they were boys two of them were offered a prize by their father if they could build a speaking machine that could pronounce words. This the two boys succeeded in doing by fashioning the piece of apparatus after the human skull and imitating in every way as nearly as possible the human elements used in uttering sounds. Later Alexander taught music and elocution.

In this work he became interested in the use of the mouth as a resonant cavity, and studied the effect of the shape and size of the cavity on the sound produced. He thought this was a new idea, and said so to one of his friends, who was a physicist. This man made him acquainted with Helmholtz's experiments with resonators responding to tuning forks. Bell concluded that it would be necessary for him to understand such experiments in order to further his understanding of the voice and of the teaching of articulation. He found it necessary then to go into the study of electricity in order to understand the behavior of the electrically operated tuning forks.

With the electrically operated tuning forks he devised circuits for sending electric currents over a wire of the same frequency as the tuning fork by

allowing one of the prongs of the tuning fork to make and break a circuit. He used this for telegraphy, and experimentally learned that it was possible by means of the tuning forks to send currents of two or more different frequencies over a wire at the same time. This led to the invention of what he called "multiple harmonic telegraphy." He used tuning forks to produce his carrier frequencies, and he used tuning forks also for receiving the messages. A tuning fork of a given frequency at one end of the line would energize the tuning fork of the corresponding frequency at the other end of the wire.

Later he was dissatisfied with the system of make-and-break, and interposed an induction coil between the tuning fork contact and the wire itself. He found then that he got two impulses for each current impulse in the local circuit, and this gave him some difficulty for a while until he hit upon the idea of moving a prong of the tuning fork in the neighborhood of a coil and thereby producing a current of the same character as the mechanical vibration of the tuning fork or reed. This idea, however, he did not try at this time, because he thought the power would be entirely too low, so he continued to use a make-and-break mercury contact.

About this time he became acquainted with Koenig's manometric capsule, which consists of a chamber divided into two parts by means of a diaphragm, which seals one part from the other. One side of the diaphragm was connected to a supply of illuminating gas through one opening and to a burner through another opening. The other side was connected to a sound collector, which opened to the atmosphere. When the flame was lighted and words were spoken, or other sounds were produced, in the neighborhood of the sound collector, these sounds produced vibrations of the diaphragm which were made visible on account of their effect on the gas pressure and on the flame. When the flame was observed in a rotating mirror it was possible to notice differences in different kinds of sound.

He became acquainted with another piece of apparatus, known as a phonautograph, a forerunner of the present oscillograph. In the phonautograph a diaphragm was fastened across the small end of a sound collector and the center of the diaphragm was connected to a system of levers which could be set in motion by the vibration of the diaphragm. The levers were made to operate a stylus which drew a wavy line on a moving piece of paper or of glass that had been covered with soot.

After this he went back to the idea of energizing a line by means of a vibrating reed in the neighborhood of an electromagnet, and devised, although he never constructed, what he called a harp. In this harp a great number of reeds were to be mounted with their free ends in the neighborhood of the poles of an electromagnet. He concluded that since the current over the wire was a composite of the currents produced by all the different reeds that there was no reason why the current should not also be produced in the same coil so that one magnet would serve the purpose for a considerable number of reeds. He thought this apparatus was too complicated to be practical.

In thinking of this piece of apparatus, however, his musical experience stood him in good stead because he remembered the fact that when one sings into a piano it is possible to produce vibrations in the strings that correspond in frequency to the frequencies in the voice. He thought that it would similarly be

possible to sing or speak to his harp and produce the voice frequencies not only in the reeds but in the coil of the electromagnet.

He then went one step farther. If it is possible to use one coil and one wire to carry the composite vibration, it should be possible also to use one reed or vibrating element. This idea followed directly from his experience with the manometric capsule and the phonautograph. In those instruments the diaphragm responded to all the different frequencies and produced a vibration that corresponded to the composite sound.

Putting all that together Bell next had the idea of using a diaphragm to move the end of a reed which should be mounted in close proximity with the pole of an electromagnet so as to transform the mechanical vibrations of the diaphragm and the reed into electric currents.

At this stage Bell was embarrassed with the fact that it was difficult for him to get the financial help that was necessary to carry on these experiments. He went to Washington on an errand in connection with the prosecution of his patents, and there met Henry, and told him of his ideas and told him also that he thought possibly it would be better to let someone else develop them. Henry advised against that, and said that he thought Bell had the germ of a great invention and that he ought to develop it himself. Bell said he did not have the necessary electrical knowledge, to which Henry responded, "Get it."

After this encouragement and upon his return from Washington he got financial help from two of his friends and hired a mechanic. His friends who were practical minded men insisted that he develop his multiple harmonic telephone first because they thought that was more likely to be immediately practical. He and his mechanician Watson first tried to build a triple frequency telegraph system, the power to be transmitted by making and breaking the circuit. They found a great deal of difficulty in tuning the corresponding reeds at opposite ends of the circuit to one another. Accidentally one day one of the reeds stuck so that the contact would not open, and Watson was plucking it to produce vibrations when Bell came running into the room from the room containing the other end of the wire, and asked him what he was doing at that time and not to change anything becauuse he had gotten results. Watson repeated the plucking and they found then that the reed had stuck so that the contact was not opening, but the vibration of the reed in the neighborhood of the magnet was producing a current that affected the reed at the other end. This was exactly what Bell had predicted some years before but had never succeeded in carrying out. The fact that it was possible by moving a piece of steel in the neighborhood of an electromagnet to get a sufficient electrical impulse to transmit it over a wire and to energize a piece of apparatus at the other end was all that was needed for Bell to complete his speaking telephone. He now had all the elements. A vibrating diaphragm will receive and reproduce all the pressure changes in the atmosphere, and a reed attached to the vibrating diaphragm and allowed to vibrate in the neighborhood of a pole of an electromagnet will transform these from mechanical vibrations into electrical oscillations which can be transmitted and received at some distance away on the same wire. The apparatus was designed and built on that principle. It did not work at first, and in order to get additional financial help it became necessary for Bell to discontinue his

experiments for a year. When he came back to it the telephone was completed, although at first in a somewhat different form.

This experience of Alexander Graham Bell and his accomplishment is an excellent illustration of the point that I am trying to make, namely that the imagination makes use of only known elements and goes by very small steps from one stage to the next in any development. Bell made use of all his experience with the human voice and a study of the parts that are necessary to produce it, and an anatomical study of the human ear and the functions of the parts that enable the ear to receive sound. He combined that knowledge step by step with the knowledge of electrical and mechanical devices with which he gradually became acquainted, and the result finally was a rather crude telephone, which gradually developed into the excellent piece of apparatus that we know today.

It was the result of many years of work.

An amusing illustration of the lack of imagination when applied to something new in people who are otherwise very practical is found in the experience of the Merritt Brothers when they discovered iron ore lying on or near the surface of the ground in Northern Minnesota. When they tried to interest capital to mine this material, they were told that was ridiculous. How could anyone sink a shaft where the ore was right on the surface of the ground? A new method of mining had to be developed, namely the simple use of a steam shovel.

In conclusion I want to extend the thoughts that I have expressed here beyond the fields in which I am experienced. As I have said already we are dependent upon invention in all lines; for instance, speech was invented probably during a very long period, languages have to be invented or developed, writing, painting, domestication of animals, the use of artificial light, heat, the organization of government, the making, the use, and the enforcement of law, economical systems, sociological relations, social and governmental units, the process of buying and selling instead of simply taking things from one another, all had to be invented so that in our social relations we are dependent throughout on invention and the use of imagination. It is unfortunately true, however, that while we have learned to go about making developments systematically in the case of physical problems and some biological problems, we have not yet learned to apply imagination deliberately, and to do systematic inventing when it comes to social, governmental, or international relations. In government, for instance, we seem to grow more or less like Topsy. In the past the strong man in the tribe or the strong man in the larger group, finally in the nation, became the king, or the ruler, or the dictator. In the democracies we elect Presidents. In communisms we have other forms of government. We do not seems to be trying systematically and objectively to work out any conclusion as to which of these schemes is the best and the most profitable for all concerned. There are many things that might be mentioned. Just recently I heard a discussion about a detail, namely the Presidency of the United States. The first term is apparently largely lost on account of the fact that the President has to play politics so as to get a chance to continue to work for another four years. If he succeeds in getting a second term and is naturally interested in politics, the

second term is also largely lost because he wants to see his policies continued. After the second term he is usually laid on the shelf. Even with the best of intentions, much of his value is lost. Someone should be assigned to study the psychological and other aspects of this problem, and to suggest a way of getting the full benefit of the President's capabilities while he is in office, and to continue to get the benefit of his experience after he has completed his term in the presidential chair. It has been suggested, for instance, that he should have only one term, four or six years, or whatever is considered practical, and that after that term it should not be incumbent upon him to indulge in any more politics because he would become a Senator-at-Large for life. That may or may not be a good suggestion, but someone should be studying such questions, and our lawmakers should realize the importance of systematic planning. Possibly we should do something about the training of our lawmakers, for instance so that they would know something about what laws are, how they are made, and what their responsibilities involve.

In economics, we are in about the same situation. We have learned to buy and sell to be sure, but we insist on profits which are sometimes hidden and not allowed to work immediately. The result is that over long periods, buying power becomes inadequate. When that is the case, up to a certain point, credit is given by those who have the means. When credit has gone as far as the creditors are willing, buying disappears. We then have what we call a "crash." Something is wrong with our equation between buying power and production. Someone should be trying systematically to find out what this discrepancy is, and how it can be corrected. We are not doing that. We have individual research organizations which are doing their best, but they do not have the authority either to suggest or to enforce any of their suggestions upon the lawmakers.

It seems to me that while a great deal of thought is being put on the subject of education and how to make it more effective, we are failing in the same way there. We are not making a systematic study. The study that is being made is very haphazard. The experiments are dependent too much on the reaction of those who are experimented upon, or the reaction of the public so that it is impossible to complete them satisfactorily. Here is a place where imagination should be given full play to the end that sooner or later someone will invent a system or part of a system which will be effective. I think in our present educational process many things are obsolete, and some of the fundamentals of learning have been lost sight of. I think the lecture system is such an element. We learn by doing, not by listening, but here again I may be getting into controversial ground, so we shall go on.

It seems to me that our international problems probably require at the present time the application of imagination and invention more than any other field. If we could get our international problems solved, or could arrange that they would be considered in systematic manner, I believe that some of the problems of assimilation of the products of physical science would be solved. Our imaginations here again seem to me to work very, very slowly. In the development of government we have first the family, the tribe, the state, the nation, and an empire, and we stop just short of what has been sometimes called

a Federation of the World. Why isn't it possible to form a Federation of the World? It seems to me that it must be, and that if we allow our imaginations to travel along the lines that have already been followed, we can see how it can be done. It seems to me the problems are exactly the same as the problems of the governmental organization of a frontier town, such as we could imagine a gold-mining or iron-mining town to be when it first comes into being in the wilderness. There is no government. Everyone carries his six-shooter and protects himself and his property as well as he knows how. Some are more acquisitive than others and try to monopolize what is available. This goes on for some time and the disorder that results finally stirs someone who remembers conditions elsewhere to suggest that a government be established. The first important official in such a government is the sheriff, a policing force. The bullies in the town who have had their own way are not in favor of a government, but the men who realize that it is best for everyone to have systematic control of the behavior of the individual insist upon it, and the bullies either have to submit in the end or they have to leave. Exactly that same development is gone through in all governmental structures. In Viking days there was a king, and sometimes more than one king, in every valley of Norway. Finally came one with vision and strength enough to subdue these kings one after another and make Norway a united nation. It was necessary to use force. They were not all willing to go into a union of this kind.

The same was true in the United States of America. It was difficult to get everyone to agree, and there was talk of wars between the different colonies. In the 1860's we had a war because some of the states were not willing to submit to rule of the federal government. That kind of coercion occasionally seems to be necessary. When we come to international organization, however, our imaginations are not able to carry on. We tried a League of Nations in which every nation should be perfectly free to come and go as it chose. The result is that it is now partially dismembered and very weak. That will always be the result until we realize that it is necessary for the good of all to organize and to enforce the union. When enough of the nations of the world are willing to cooperate in the organization of an international police force, it will be possible to organize a Federation of the World. Until we come to realize that that is necessary, such a Federation is probably not possible. Again our imagination proceeds in very small steps and sometimes with long intervening time intervals, but the imagination is necessary, and invention is necessary, and the only restriction upon them must be the restriction imposed by knowledge, experience, and understanding of the elements that are used in the construction.

From what has been said it seems to me there may be drawn a lesson of encouragement for youthful members of Sigma Xi. "Rome was not built in a day," and worth while results in research are usually reached by long effort and as a result of many small elements of progress. At the same time our consideration leads to the conclusion that by conscious, energetic, and persistent exercise of the imagination, it can be stimulated so that the rate of progress is very much increased. It is important that the effort shall be conscious and deliberate and the reward is great.

HALF CENTURY RECORD AND HISTORY

Compiled by

HENRY BALDWIN WARD

and

EDWARD ELLERY

A Volume of 1,208 Pages

Gives the history of the National Society, the history of each of the seventy chapters, the history of each of twenty-six clubs, and the record of each of over forty thousand members and associates.

Now available to all members and associates of Sigma Xi, and to libraries of educational, and research, institutions at the price of $3.50.

Orders with check should be sent to the National Secretary, Edward Ellery, Union College, Schenectady, N. Y.

SIGMA XI LECTURE SERIES FOR 1940

Lecturers, lectures, and available dates of the third series of Sigma Xi lectures are announced by the Committee on Lectures as follows:

Lecturer: Professor F. W. Went.
Topic: The Regulations of Plant Growth.
Available Dates: Last two weeks in January.

Professor Went is Professor of Plant Physiology at the California Institute of Technology. He came to the Institute in 1933 from the Botanical Gardens of Buitzenorg, Java, where he had been Director of the Foreigners Laboratory. His research work has been done in plant hormones, plant growth, phototropism, root formation, polarity, the water relation of plants, ecology of spiphytes.

Lecturer: Professor J. F. Fulton, M.D.
Topic: The Functions of the Frontal Lobe; an Experimental Analysis in Monkeys, Chimpanzees and Man.
Available Dates: First two weeks in February.

Doctor Fulton is Sterling Professor of Physiology, in the School of Medicine of Yale University. His experience includes association with Magdalen College of Oxford University, and with the Peter Bent Brigham Hospital in Boston. His investigations cover the blood pigments of invertebrates, especially of Ascidians, the nature and significance of the electrical response of contractile tissues, the reflex coordination of movement and posture, and the comparative physiology of the primate brain.

Lecturer: Professor J. W. Beams.
Topic: High Speed Centrifuging.
Available Dates: First two weeks in March.

Professor Beams is Professor of Physics at the University of Virginia His researches include the measurement of very short time intervals, the Keer effect, electrical discharges, and ultra-centrifuges.

Lecturer: Professor Douglas Johnson.
Topic: Mysterious Craters of the Carolina Coast.
Available Dates: Last two weeks of March.

Professor Johnson is Professor of Physiography at Columbia University and Executive Officer of the Department of Geology and Mineralogy. He has filled national and international positions of importance. He has been connected with the United States Geological Survey, and has been geological adviser of the United States Department of State. He was Consulting Physiographer for the Canadian Government in the Labrador boundary dispute. He has been awarded medals by many societies in this country and Europe. His researches include the physiography of lands, shore-line physiography and military geography.

Lecturer: Dr. D. A. MacInnes.
Topic: The Motions of Ions and Proteins in Electric Fields.
Available Dates: Last two weeks of April.

Doctor MacInnes is associated with the Rockefeller Institute for Medical Research in New York City, and was formerly Associate Professor of Physical Chemistry at the Massachusetts Institute of Technology. His research work has been done in the field of solutions of electrolytes and of electrochemistry.

CHAPTER OFFICERS

List Furnished by the Secretaries of the Chapters

Chapter	President	Vice-President	Secretary
Cornell	J. M. Sherman	C. C. Murdock	L. Spencer
Rensselaer	G. H. Carragan	P. E. Hemke	E. J. Kilcawley
Union	F. J. Studer	E. M. Ligon	A. H. Fox
Kansas	H. B. Hungerford	A. W. Davidson	W. H. Schoewe
Yale	E. J. Miles	F. T. McNamara	L. F. Nims
Minnesota	E. T. Bell	E. W. Davis	E. A. Donelson
Nebraska	M. G. Gaba	J. E. Weaver	E. R. Washburn
Ohio State	H. C. Sampson	L. H. Snyder	P. B. Stockdale
Pennsylvania	D. H. Wenrich	J. H. Austin	R. Morgan
Brown	R. B. Lindsay	Z. R. Bliss	P. H. Mitchell
Iowa	E. W. Chittenden	E. Bartow	D. Lewis
Stanford	L. M. Terman	G. S. Parks	K. M. Cowdery
California	C. D. Shane	H. Kirby	L. E. Reukema
Columbia	H. W. Webb	A. W. Thomas	D. P. Mitchell
Chicago	D. B. Phemister	R. T. Chamberlin	V. E. Johnson
Michigan	H. H. Willard	M. H. Soule	F. L. Everett
Illinois	L. A. Adams	L. E. Card	P. W. Ketchum
Case	F. Whitacre	R. Shankland	R. L. Burington
Indiana	R. J. Hartmann	R. E. Esarey	M. L. Lohman
Missouri	W. D. Keller	R. T. Dufford	B. Bennitt
Colorado	I. C. Hall	W. Thompson	H. Hoffmeister
		C. A. Rymer	
Northwestern	C. H. Behre, Jr.	A. C. Ivy	N. C. Jamison
Syracuse	V. F. Lindeman	N. E. Artz	J. Russell
Wisconsin	L. R. Ingersoll	R. A. Brink	J. G. Winans
Univ. of Wash.	T. G. Thompson	J. I. Rowntree	Rex Robinson
Worcester	A. H. Holt	H. B. Feldman	W. E. Lawton
Purdue	M. G. Mellon	C. J. Klemme	E. J. Kohl
Washington Univ.	A. S. Gilson	P. R. Rider	Florence M. Heys
Dist. of Columbia	O. H. Gish	O. S. Adams	S. F. Blake
Texas	A. Romberg	D. McConnell	G. H. Fancher
Mayo Foundation	W. D. Shelden	R. M. Wilder	E. V. Allen
N. Carolina	H. D. Crockford	J. W. Huddle	J. E. Magoffin
N. Dakota	E. O. North	C. R. Byers	A. R. Oliver
Iowa State	C. Y. Cannon	J. M. Aikman	D. L. Holl
Rutgers	D. L. Cottle	W. R. Robbins	Mrs. F. T. Starkey
McGill	B. P. Babkin	T. H. Clark	J. B. Phillips
		O. Maass	
Kentucky	M. M. White	O. Koppius	L. H. Townsend
Idaho	H. S. Owens	J. Ehrlich	G. Woodbury
Swarthmore	R. B. MacLeod	E. H. Cox	H. J. Creighton
Oregon	A. H. Kunz	W. R. Todd	K. S. Ghent
Virginia	G. T. Wayburn	J. E. Kindred	J. K. Roberts
Johns Hopkins	J. C. Hubbard	Ernst Cloos	M. W. Pullen
Calif. Inst. of Technology	W. V. Houston	C. B. Millikan	J. van Overbeek
New York	H. A. Taylor	W. F. Ehret	F. E. Myers
Cincinnati	G. E. Cullen	F. O'Flaherty	S. B. Arenson
Mich. State	C. A. Hoppert	P. J. Schaible	F. C. Strong
Arizona	Lila Sands	D. M. Crooks	F. E. Roach
Lehigh	H. A. Neville	C. A. Shook	C. D. Jensen
Maryland	C. E. White	R. G. Rothgeb	R. Bamford
Kansas State	R. C. Smith	A. B. Cardwell	G. A. Filinger
Col. of Medicine Univ. of Illinois	W. H. Welker	I. Pilot	I. Schour
Pennsylvania State	R. D. Anthony	F. Stewart	F. G. Merkle
Oklahoma	G. L. Van Lear	J. A. Colbert	M. Hopkins
State Col. of Wash.	J. Sotola	N. S. Golding	O. Biddulph
Wyoming	C. S. Gilbert	W. B. Owen	F. C. Freytag
Rochester	B. O'Brien	E. Adolph	K. U. Smith
Pittsburgh	O. H. Blackwood	F. C. Jordan	A. E. Staniland
Harvard	C. H. Berry	C. F. Brooks	F. M. Carpenter
Western Reserve	F. Hovorka	T. J. Hill	J. C. Gray
Princeton	A. M. Greene	E. G. Butler	H. N. Alyea
Duke	W. J. Seeley	J. J. Gergen	C. G. Bookhout
California At Los Angeles	W. J. Miller	F. S. Fearing	M. S. Dunn
Massachusetts Inst. of Technology	S. C. Prescott	W. C. Voss	A. A. Ashdown

CHAPTER OFFICERS– *Continued*

Chapter	President	Vice-President	Secretary	Treasurer
.....	W. L. Duren, Jr.....	Charlotte H. Boatner.	H. Cummins	H. Cummins
.....	H. B. Goodrich.....	F. Slocum	J. W. Peoples.....	J. W. Peoples
.....	R. F. Collins.....	N. M. Mohler.....	L. T. Slocum.....	E. J. Gibson
.....	A. T. Lincoln.....	L. M. Gould.....	C. A. Gingrich.....	C. A. Gingrich
Washington...	G. H. Cartledge.....	G. E. Youngburg....	M. C. Swisher	H. F. Montague
.....	F. M. Weida.....	G. B. Roth.....	I. B. Hansen.....	F. M. Mears
.....	M. B. Hogan.....	H. Schneider	J. R. Lewis.....	J. R. Lewis
e Inst. of				
.....	J. B. Rosenbach.....	C. R. Fettke.....	H. C. Howard.....	R. T. Gabler
State	J. E. Simmons.....	H. A. Scullen.....	W. D. Wilkinson...	G. W. Gleason
.....	A. C. Chandler.....	.....	G. H. Richter.....	J. H. Pound
setts State..	H. Van Roekel.....	C. P. Alexander.....	Helen S. Mitchell..	W. H. Ross
.....	Ruth Johnstin	M. J. Zigler.....	H. W. Dodson...	H. W. Kaan
.....	C. F. Byers.....	R. B. Becker.....	L. M. Thurston.....	D. Williams
irginia	A. M. Reese.....	O. Rex Ford.....	C. L. Lazzeli..	J. H. Gill
.....	E. B. Carmichael....	J. D. Mancill.....	E. B. Richards.....	B. W. Gandrud

SIGMA XI CLUBS

Club	President	Vice-President	Secretary	Treasurer
California .	R. W. Truesdail....	.....	F. M. Baldwin.....	J. A. Hartley
Denver	B. Cohn	.....	Margaret Boos	Margaret Boos
Maine	E. R. Hitchner.....	W. E. Bradt.....	B. Speicher	B. Speicher
State				
M. College..	N. A. Christenson...	D. F. Costello.....	Ruth Summer	Ruth Summer
State U....	R. L. Menville.....	L. W. Morris.....	H. J. Bennett.....	H. J. Bennett
Arkansas.....	W. S. Dyer.....	.....	W. R. Horsfall.....	W. R. Horsfall
ter of				
Davis.....	G. A. Richardson....	.....	T. H. Jukes.....	T. H. Jukes
niversity	W. W. Atwood.....	.....	P. M. Roope.....	P. M. Roope
Univ.....	D. W. MacCorquodale	L. F. Yntema.....	A. E. Ross.....	.....
Connecticut...	W. L. Kulp.....	F. Heiser.....	H. W. Hunter.....	H. W. Hunter
University ...	W. H. Shideler.....	.....	R. V. Van Tassel....	R. V. Van Tassel
Georgia.....	D. C. Boughton.....	.....	G. W. Crickmay.....	G. W. Crickmay
University..	W. D. Garman.....	.....	J. D. Stetkewicz.....	.....
A. and				
ollege	J. C. Ireland.....	D. I. Purdy.....	J. E. Webster.....	J. E. Webster
State Coll...	D. B. Swingle.....	H. T. Ward.....	P. L. Copeland.....	P. L. Copeland
Dakota				
College	L. M. Roderick.....	H. H. Flor.....	H. E. Wirth.....	H. E. Wirth
ech. Coll....	W. M. Craig.....	E. L. Reed.....	W. W. Yocum.....	....
Montana	F. O. Smith.....	G. D. Shallenberger..	C. W. Waters.....	.....
Poly. Inst...	P. C. Scherer.....	F. B. Haynes.....	W. J. Schoene.....	J. A. Addlestone
China	K. P. Young.....	H. C. Chang.....	P. P. T. Sah.....	P. P. T. Sah
.....	W. A. Ver Wiebe....	C. C. McDonald.....	E. A. Marten.....	E. A. Marten
niversity	C. A. Frey.....	D. B. Green.....	C. Denbow	C. Denbow
w Mexico..	R. E. Holzer.....	G. V. Martin.....	L. S. Gill.....	L. S. Gill
ansas City....	Grant Smith	K. L. Mahony.....	C. W. Sondern.....	C. W. Sondern
nic Institute				
klyn	R. E. Kirk.....	C. C. Whipple.....	W. H. Gardner.....	W. H. Gardner
ns Univ.	H. P. Pettit.....	D. R. Swindle.....	J. F. H. Douglas.....	.....
.....	Mary Pinney	.....	M. J. Martin.....	.....
Institute	D. P. Boder.....	.....	Helen S. Mackenzie..	.....
.....	F. M. Hull.....	A. B. Lewis.....	G. W. Parsons.....	G. W. Parsons
.....	R. G. Daggs.....	C. E. Braun.....	P. A. Moody.....	P. A. Moody
Agr. Coll....	S. Maeser	J. S. Williams.....	L. B. Linford.....	L. B. Linford
Young				
.....	J. K. Nicholes.....	.....	M. Marshall.....	M. Marshall
ollege	C. Welty	.....	N. Bennington	N. Bennington
Poly. Inst...	W. D. Salmon.....	G. Volk	K. C. Barrons.....	.....
niversity ...	O. R. Quayle	J. H. Purks.....	E. Papageorge	W. B. Redmond
State College.	Z. P. Metcalf.....	W. H. Browne.....	R. C. Bullock.....	R. C. Bullock
awaii	C. J. Hamre.....	M. Potgieter	S. S. Ballard.....	S. S. Ballard
State				
.....	C. Q. Sheely.....	C. H. Ragland.....	F. P. Welch.....	F. P. Welch

OFFICIAL ANNOUNCEMENTS

SIGMA XI EMBLEMS

All insignia of the Society are available only through the office of the National Secretary. They are made in various styles and sizes, and in white and yellow gold. Orders for these insignia are issued through chapter secretaries, and must be *prepaid*. Information about styles and prices may be obtained from chapter secretaries or the National Secretary.

DIPLOMAS FOR MEMBERS AND ASSOCIATES

These diplomas are available in any quantity at 10 cents each. Diplomas can be engraved with the name of the individual and of the chapter and the date of initiation at 25 cents each. Orders should be sent to the National Secretary, should specify whether for members or associates, and should be accompanied by check.

INDEX CARDS

Index cards for newly elected members and associates are available *gratis* upon requisition from chapter secretaries to the National Secretary. These cards should be made out in duplicate, one set being retained for chapter files and one set being sent to the National Secretary for filing in the permanent records of the national organization.

NATIONAL CONSTITUTION

Printed copies of the National Constitution and History of the Society are available at 5 cents each from the National Secretary.

CHANGES OF ADDRESSES

Chapter secretaries are asked to send to the National Secretary in October of each year changes in their enrollment lists as follows: 1. Names and addresses to be deleted from the previous list; 2. Names and addresses to be added to previous list; 3. Changes of addresses of those on previous list who may have moved to a new address since the list was submitted.

SIGMA XI STATIONERY

Stationery in the official color of the Society is now available for all chapters and clubs at $5 per 500 sheets and $5 per 500 envelopes. The letter sheets bear the Society's seal embossed in white but no printing. The envelopes are the official square envelopes used by the national officers. Printed heading on the sheets and printed corner cards on the envelopes can be provided at cost, when so desired.

EDWARD ELLERY,
National Secretary, Sigma Xi,
Union College,
Schenectady, N. Y.